THE NATURAL HISTORY OF THE HAKE

PART I AND II

by

C. F. Hickling

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PREFACE.

This paper seeks to serve as an introduction to a study of the general conditions in the hake fishery, and also to draw attention to some points of especial interest. It is based on observations made and experience gained during 14 months of sea-time on commercial steam trawlers fishing for hake, especially since October, 1924, and is illustrated to a considerable extent by statistical data supplied by the Ministry's Statistical Section. I wish, however, to emphasize the fact that reliance has been placed rather on first-hand observation than on statistical data, and where the latter are employed it is usually a question of confirming and illustrating points gained by practical experience.

The work was commenced at Plymouth, with the aid of a grant from the Department of Scientific and Industrial Research, and continued at Liverpool University, under the Ministry's scheme of " directed research." It is a pleasure to acknowledge my thanks to Dr. E. J. Allen, F.R.S., and the staff of the Plymouth Laboratory, for their help at the commencement of the work, and to Professor J. Johnstone, D.Sc., and Mr. R. J. Daniel, M.Sc., of the Department of Oceanography, Liverpool University, for their valuable help and advice.

The voyages were made from Milford Haven, by courtesy of Messrs. H. E. Rees & Co., from Cardiff, by courtesy of Messrs. Neale & West, and from Fleetwood, by courtesy of Messrs. J. Marr & Son. I am greatly indebted to the numerous skippers who have taken me out on their ships, and especially, perhaps, to Capts. J. Rumble and W. Jones, of Milford, and Capt. Drennan, of Cardiff, for their hospitality, and for giving me the benefit of their experience.

Finally, I have to thank my friend, Mr. Paul Reed, of the staff of the *Liverpool Post and Echo*, for his invaluable help in arranging the text of this paper.

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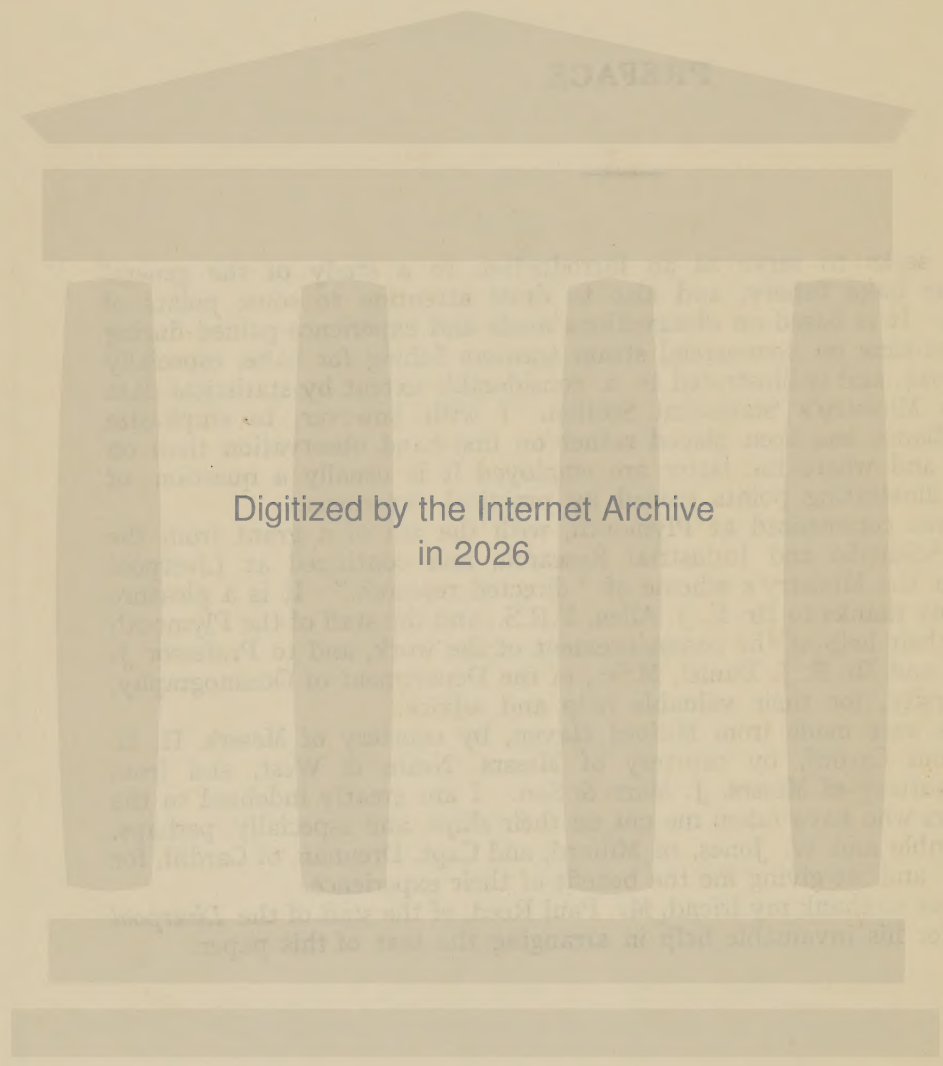

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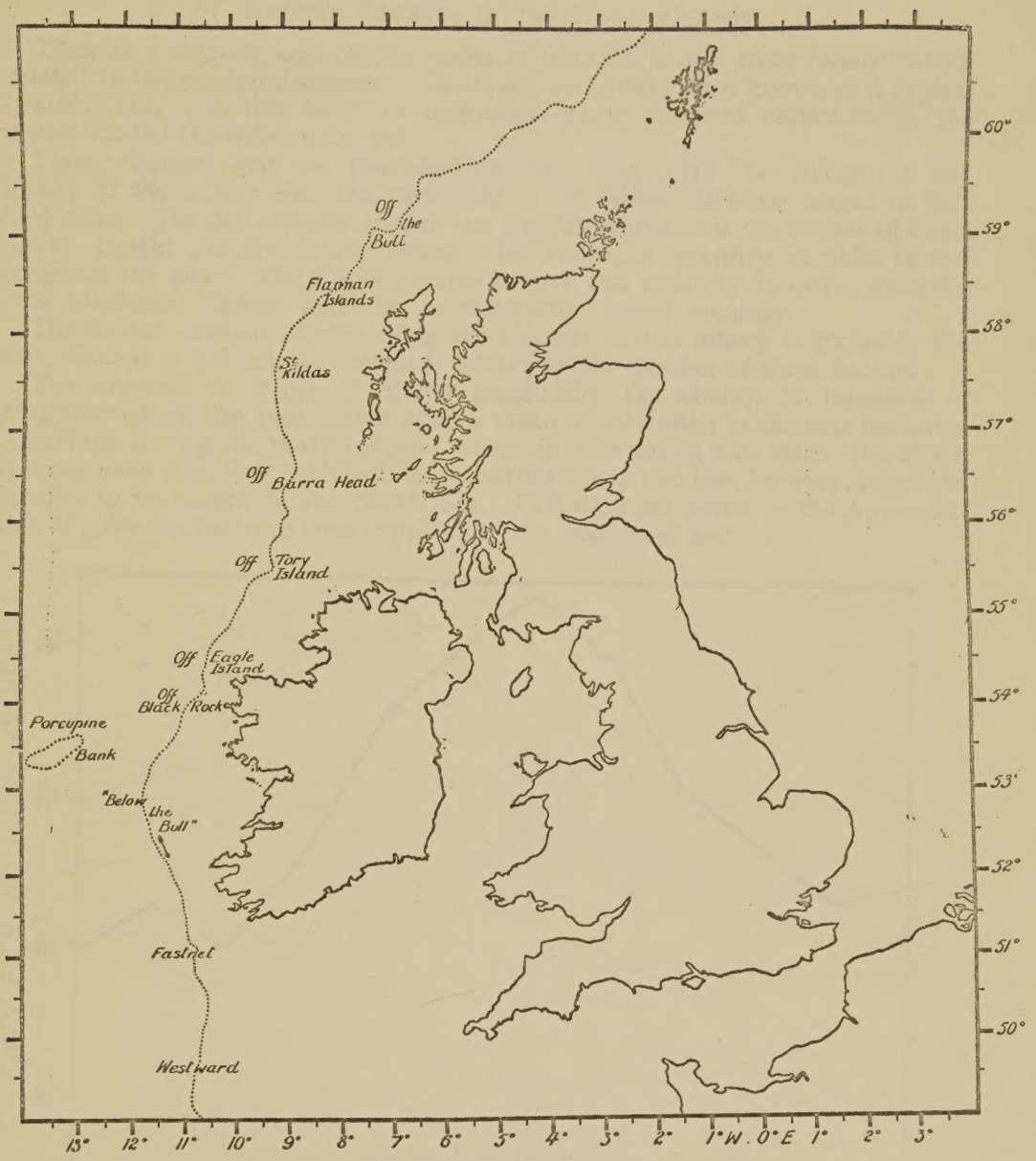
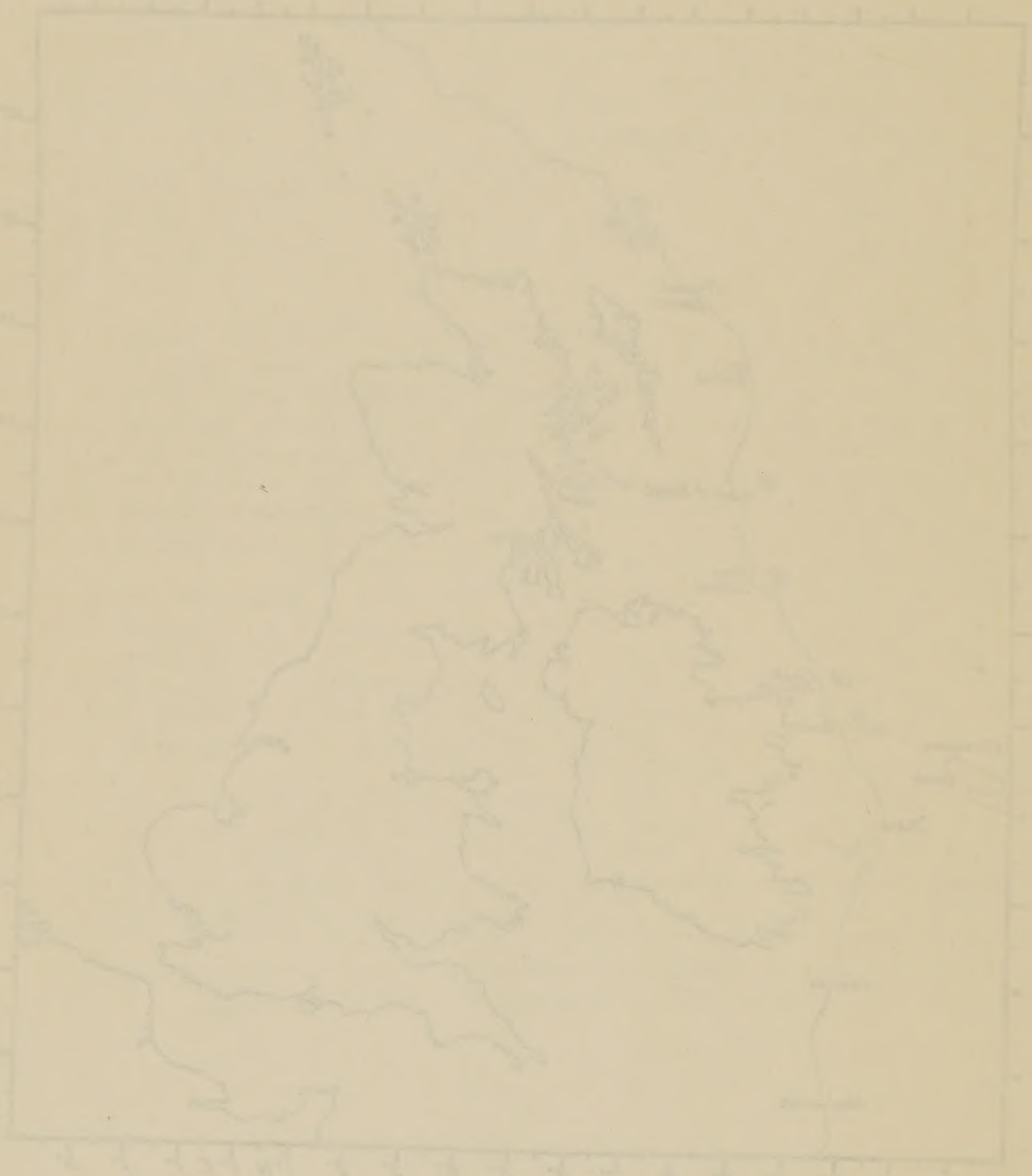


The approximate localities and usual names of the chief deep-water hake fishing areas.



PART I.

A. Annual Changes in the Hake Fishery.

There is a distinct and regular series of changes in the hake fishery, which is related to the changing seasons. The Hake has always been known as a typical migratory fish, and this habit of migration causes seasonal variations in the quantity landed throughout the year.

These changes may be examined in two ways. (1) The change in the intensity of the fishery, i.e., the variations in the weight of hake caught in unit fishing time. The unit usually used in the English statistics is the weight of hake, in cwts., caught per 100 hours' fishing. (2) The total quantity of hake landed throughout the year. The English statistics give this quantity in cwts., annually in the Statistical Tables, and also in statements issued monthly.

The former method of examining the changes in the fishery is probably the better, since it is less affected by such factors as the number of ships fishing.

The diagram in Figure 1 shows graphically the change in intensity of fishing throughout the year, based upon a mean of the fishing in all areas indicated in Chart 13, during the years 1923–5. Since, in calculating this mean, the North Sea areas have also been included, the resulting figures are low, for very little hake is usually to be caught in the North Sea. Full data are given in the Appendix, Table V; the figures have been supplied by the Statistical Section.

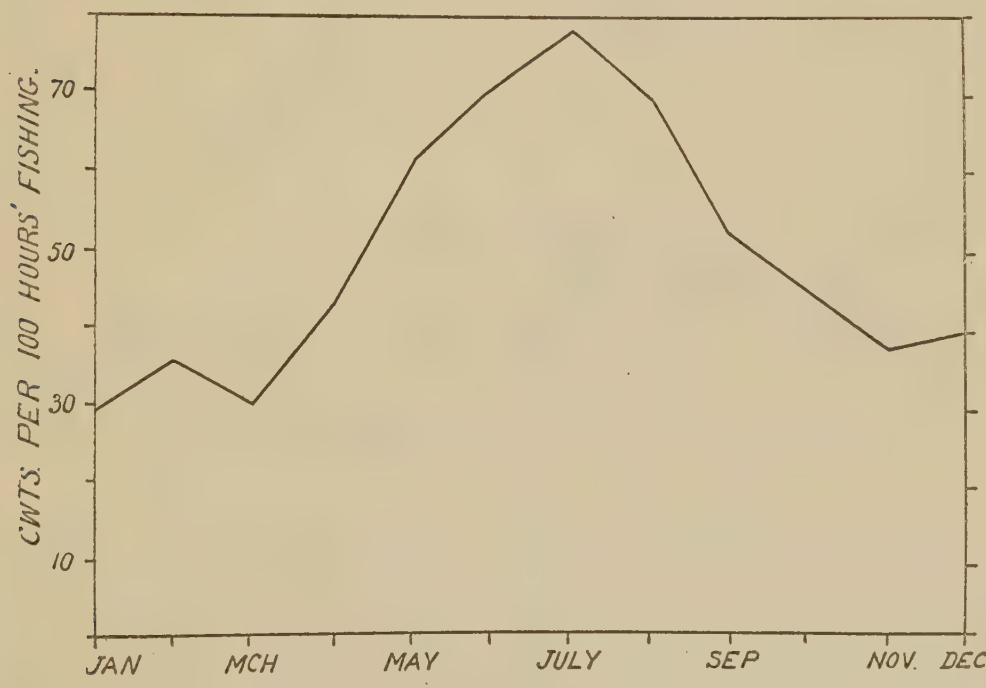


Fig. 1.—Catch of hake per 100 hours' fishing. Mean of all the regions shown in Chart 13, for the period 1923, 1924, 1925. Data in Appendix, Table V.

The figure shows that during the winter months the trawl, on the whole, will take much less fish than during a haul of the same length of time in the summer months.

This smaller average yield of fish must have its effect on the total landings of hake, since winter trips will not yield as much fish as summer trips of equal length, as stated above. Accordingly, when the total weight of hake landed per month throughout the year is discussed, it is found that much more hake is landed in the summer months than in the winter months. In Figure 2 are given curves derived from the mean monthly landings of hake for two separate periods of the fishery, namely, from 1908 to 1913 inclusive and from 1920 to 1925 inclusive. It is quite plain that the annual course of the fishery is the same in the post-war as in the pre-war years, the difference lying in the facts that in the later series of years the time of best fishing tended to lie later in the year than in the earlier series, that a smaller total quantity has been landed, and especially in the much smaller percentage of big and medium hake landed in the post-war years. This is clearly brought out in the diagram.

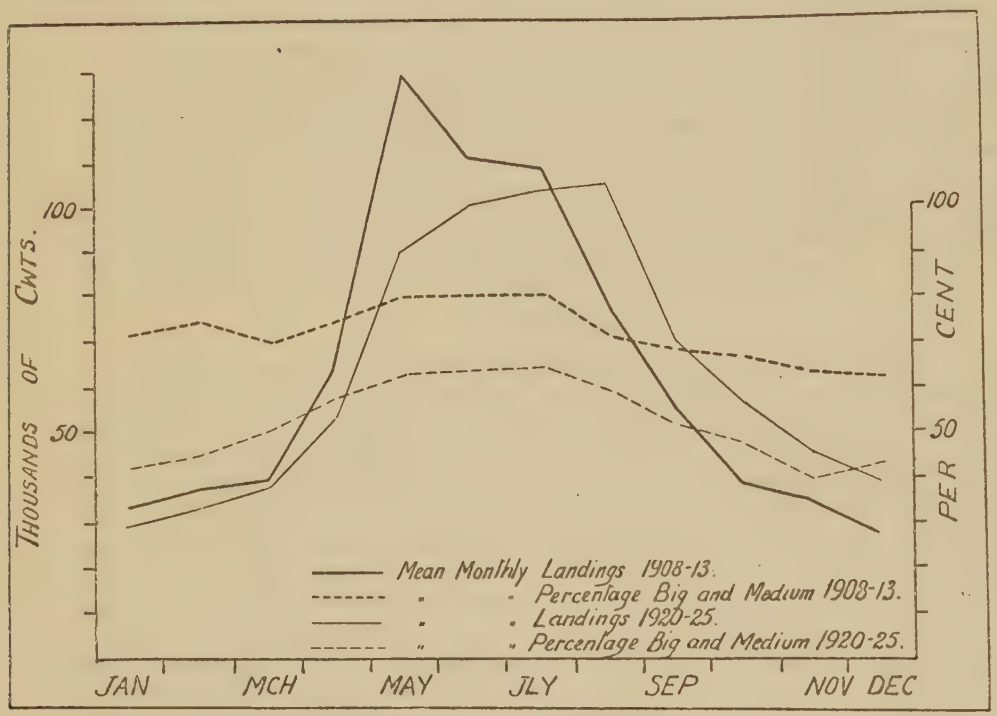


FIG. 2.—Mean monthly landings of hake in England and Wales for the periods 1908-1913, and 1920-1925, with the mean monthly percentages of big and medium hake for the same periods. Data in appendix, Table VI.

The weight of the catches in post-war years, as shown in Table VI, has therefore been brought nearly to the level of the pre-war landings by vast quantities of small hake, which have been the chief feature of the fishery in recent years. This great quantity of small hake may be accounted for, to some extent, by remembering that a smaller size of hake can be marketed now than could be marketed before the war, and that then, also, it was often not thought worth while to land all the small hake caught; but there is universal agreement among skippers that small hake are present on the fishing grounds in greater quantities than have ever before been known.

In fact, the quantity of big hake landed has undergone since 1919 a fairly steady decline, which is apparently being maintained, though since 1923 there has been a notable increase in the landings of medium hake. I have noticed, at sea, that the majority of the hake caught were of small medium size in 1926, big hake

being scarce. This probably means that a good spawning year, or series of spawning years, have stocked the fishing grounds with small immature fish, which are now beginning to pass on into the larger sizes in the ordinary course of growth. The shortage of larger sizes may be due to a run of poor spawning seasons prior to the good spawning seasons, seasons in which few of the eggs spawned developed, the effect of which is now apparent in the scanty supply of larger hake. A full discussion on these changes in the hake stock could only be undertaken in connection with extensive research on the age of hake and the year-composition of the hake shoals, work which has only been attempted in a tentative and experimental way. But there is no doubt that the hake stock present on the fishing grounds is being far too heavily drawn upon, and that the continued landings of small hake in great quantities, especially in the summer months, when they are of very little value, is a dangerous practice, and one that may have serious effect on the future stock.

B. The Annual Course of the Fishery in Different Regions.

The seasonal variations in the hake fishery on the various grounds are discussed in two ways. Firstly, a series of charts is given on which are drawn contour lines representative of the quantity of hake caught; the movements of these contour lines show the seasonal movement of the areas of good fishing.

Secondly, the fishing grounds about the British Isles are divided into regions which represent, as nearly as I can judge, natural hake areas. The course of the fishing in each area is then shewn graphically and discussed.

Charts 1–12.

These charts are constructed from data for which I am indebted to the Statistical Section. The method of collecting the statistics, and valuable comments on their use and reliability, are given by Edser (1925). In this method, the landings of hake are referred to the region in which they were caught, and for this purpose the fishing grounds are divided into rectangles, each of 30′ of latitude by 1° of longitude. A monthly chart has been supplied by the Statistical Section which shews, for each rectangle, the total catch during the month, and also the average catch, in cwts., per 100 hours' fishing. It is from the latter figure that Charts 1–12 have been constructed.

The fishing intensity, i.e., the catch of all classes of hake per 100 hours' fishing has been graded into an arbitrary scale of groups, each group being represented by a number. The groups are as follows:—

Table I.

Group 00.	Average Catch.		Under 10 cwts. per 100 hours' fishing.
0	,,	,,	10 and ,, 20 ,, ,, ,, ,, ,,
1	,,	,,	20 ,, ,, 50 ,, ,, ,, ,, ,,
2	,,	,,	50 ,, ,, 100 ,, ,, ,, ,, ,,
3	,,	,,	100 ,, ,, 150 ,, ,, ,, ,, ,,
4	,,	,,	150 ,, ,, 200 ,, ,, ,, ,, ,,
5	,,	,,	200 ,, ,, 250 ,, ,, ,, ,, ,,
6	,,	,,	250 ,, ,, 300 ,, ,, ,, ,, ,,
7	,,	,,	300 ,, ,, 350 ,, ,, ,, ,, ,,
8	,,	,,	350 ,, ,, 400 ,, ,, ,, ,, ,,
9	,,	,,	400 ,, ,, 450 ,, ,, ,, ,, ,,
10	,,	,,	450 ,, ,, 500 ,, ,, ,, ,, ,,
11	,,	,,	500 ,, ,, 550 ,, ,, ,, ,, ,,
12	,,	,,	550 ,, ,, 600 ,, ,, ,, ,, ,,

Referring to the montly charts mentioned above, to each rectangle I have applied its appropriate number. The numbers have then been included in "contour lines" of fishing intensity in the following way.

Contour lines are drawn, such that the first encloses all areas from which hake has been landed at all. The second contour line encloses areas where the intensity of fishing is greater than group 1 of the arbitrary scale, but less than group 4, i.e., when the fishing intensity lies between 50 and 150 cwts. of hake per 100 hours' fishing. The third contour line encloses areas where the fishing is better than 150 cwts. per 100 hours' fishing, i.e., it encloses groups higher than, and including, 4. The contour lines have been left open on the seaward side, because there is good reason to believe, with Schmidt (1908), that the hake can, and actually does live a pelagic life freely over the deep water.

Beside these three most important contour lines, other lines are drawn in Charts 1–12, where there are local concentrations of special interest, as in the North Sea, or, where there is exceptionally heavy fishing, as in many cases to the south and west of Ireland, and to the west of Scotland.

The contour lines may be taken to mean this: the first line indicates the distribution of hake, at least in sufficient quantity to be landed; the second line bounds areas where sufficient hake is landed to form an appreciable part of the catch, and in some circumstances also to make a profitable voyage. The third line bounds those areas where fishing is good enough to make it worth a ship's while to fish for hake alone—it is the region of relatively "good fishing." In studying seasonal changes in the hake fishery, it is this region which is of chief interest, hence it is distinctively stippled in the charts so that its movements may be readily followed.

The figure for "good fishing" was roughly estimated by Capt. Drennan. He considers that not less than 170 cwts. (boxes) of hake must be caught in 100 hours' fishing time to enable a big trawler to pay her way. This works out, in a winter voyage of 9 days' fishing of 16 hours each, with 1½ hours lost in hauling and shooting (shooting at 5 a.m. and hauling for the night at 9 p.m.) to a landing of 222 boxes of hake. But whether this would constitute a good trip would depend entirely on the state of the market and the quantity of big and medium hake included in that total. Unfortunately, the word "hake" means, to a skipper, big and medium hake only, small hake being classed with "other sorts." However, the estimate is close enough to give a working average, and we may therefore consider that areas where the fishing is of group 4 or better (i.e., more than 150 cwts. per 100 hours' fishing), roughly indicate the region of the important hake fishery.

On the other hand, it must be understood (*a*) that less than 150 boxes (= cwts.) of hake (in the statistical sense) per 100 hours may make a good trip if it consists largely of big and medium hake; (*b*) that the figures for each rectangle of fishing ground are average figures, so that skilled skippers could make good trips in areas where the average figure seems relatively low; (*c*) that other fish landed with the hake, such as bream, conger, lings, rays, black jacks (*Gadus virens*), etc., may make up a profitable trip in an area where the statistics indicate relatively low catches of hake. These points refer only to group 3.

The heavily stippled area, therefore, which includes regions of good fishing, is the most interesting from the present point of view. In the following notes it will be referred to as "good fishing" or as "the hake fishery." Especial reference will also be made to the general distribution of hake in the North Sea, which is of considerable theoretical interest.

One further note is necessary before commencing a discussion of Charts 1–12. I have manipulated the contour lines slightly, in certain circumstances, where my experience has indicated that this is necessary to give greater accuracy. For instance, hake described as caught at St. Kilda, or the "Kildas," during the winter months, is actually caught beyond the 100 fathom line, up to 30 miles away from the islands. In these cases I have drawn the contour line just beyond the 100 fathom line.

In recent years also, good trips of hake have been landed, during the winter, from the "Norwegian Deep Water," in 100 fathoms and more, and where the charts for the winter months show high catches in that region, I have drawn the contour lines within the deep channel.

Thirdly, it is well known that, during the winter, in the south-western area, and west of Ireland (on the Westward grounds, the Fastnet grounds, and "below* the Bull"), the hake is then caught, in quantity, in the deep water, beyond the 100 fathom line, and usually from 150 to 300 fathoms and more. But the continental slope is everywhere very steep here, and I have accordingly shifted the contour lines, based on rectangles which border the deep water, so that they lie beyond the 100 fathom line.

If these precautions are taken in drawing charts which are based on statistical evidence only, I think that a reasonably faithful idea of the annual change in the hake fishery may be obtained from them.

Charts 1–12 represent the state of the fishery in March, June, September and December, respectively, for the years 1923, 1924, and 1925. It is at once apparent that the three years show a regularly repeated series of changes. The charts also illustrate, to some extent, the increasing precision of the information as to fishing grounds obtained by the collectors of statistics, for the years 1924 and 1925 give much fuller data than the year 1923.

March. (Charts 1, 5 and 9.)

In *March, 1923* (Chart 1), there was nowhere, apparently, a greater concentration of hake than 100–150 cwts. per 100 hours' fishing, i.e., nowhere "good fishing" in the meaning of the term defined above. The regions of best fishing lay along the 100 fathom line in the areas S.W. and West of Ireland, with local concentrations off the Smalls, in the deep water of the North Channel and in the Minches. By comparison with the same month in 1924 and 1925 it seems justifiable to suggest that this apparent total absence of areas of good fishing may be due to the fact that the collection of this type of statistics had only recently been extended to these areas and the initial difficulties had not been fully overcome.

The North Sea was almost clear of hake except for a thin tongue-shaped region in the extreme north, and a second distinct tongue passing in between the Orkneys and the Shetlands. The quantities taken here were very small.

In *March, 1924* (Chart 5), we find that good fishing occurred in several distinct areas. The most southerly was in the Bay of Biscay, where hake were being caught in the deep water. Northward of this, there was good fishing on the Westward ground, where, at this time of the year, hake are taken from 120 fathoms down to 300 fathoms and deeper (Lat. 49° 50′ N. and southward). To the north of this there was an area of good fishing off the Fastnet, which had moved in, as a wedge, into the shallow water. Northward of this, again, there was good fishing "below the Bull" (Lat. 53° N. and thereabouts) in water from 120 fathoms down to 180 fathoms; off Black Rock and Eagle Island there was a concentration, and west of the Hebrides was indicated the rich St. Kilda fishery, which is likewise carried on beyond the 100 fathom line. Finally, in the "Norwegian Deep Water" there was a great concentration of hake.

There was a fringe of less profitable fishing around the areas of good fishing, and there were isolated areas of local concentration in the Minches, and in the deep water in the northern part of the Irish Sea and North Channel.

In the North Sea there was a tongue of hake in the northern part, but only a very small quantity of hake was caught.

In *March, 1925* (Chart 9), the most southerly area of good fishing was in the deep water off Belle Isle (Bay of Biscay). Areas of good fishing also occurred on the Westward grounds and all along the edge of the deep water to the Fastnet,

* i.e., on the grounds reached on a course usually about N.N.W. of Bull Rock Lighthouse.

where, as in 1924, there was an invasion into the shallow water. There was good fishing in Latitude 53° N. and thereabouts, in deep water, off St. Kilda, and in the Norwegian Deep Water.

There was a fringe of moderately good fishing in the shallow water near the areas of good fishing, especially "between the Banks," and there were local concentrations of hake in the Minches (especially east of Barra Head, where fishing was good, on this chart), in the deep water of the North Channel area, and off the Smalls.

Hake were found in the North Sea over rather a greater area than in March, 1923 and 1924, but, as in these years, was confined to the northern part.

Summing up the March charts for the three years, one may say that, generally speaking, the best hake fishing is found in the deep water, especially on the Westward grounds, the outer Fastnet grounds, below the Bull, off St. Kilda and in the Norwegian Deep Water.

Local concentrations of hake occur constantly in the deep parts of the Irish Sea area, in the Minches, and off the Smalls. A fringe of rather poorer fishing is found inshore of the deep water fishery, especially in the region of the Banks (Cockburn, Labadie, etc.).

In 1925 there was a good fishery in the Bay of Biscay, but hake is very fitful in its appearance there, and the fishery was apparently a failure in 1923 and 1924. I am told that in 1926 it has not been worth exploiting. Before the war, on the other hand, there was a fairly regular fishery, worked from Plymouth and the South Wales ports, in the spring months.

It is noteworthy that, in both 1924 and 1925, there was good fishing in the shoal water off the Fastnet in March (60 fathoms). This is the beginning of the spawning run of the mature hake into shoal water. In March, 1925, these hake had penetrated as far in as the Old Head of Kinsale, for in a "dip haul" off the Old Head on March 26th, I saw four big hake taken, measuring respectively 102, 100, 98 and 77 cms., whose roes were actually running with eggs. On March 28th, 1924, big hake with ripe roes were being caught off the Fastnet in 60 fathoms to the extent of 18 score a haul.

June. (Charts 2, 6, 10.)

June, 1923 (Chart 2). In this chart we may see that, in the S.W. area, the region of good fishing had spread in over shallower water, and now extended over the Banks and up towards the Smalls. There was an area of good fishing "below the Bull," in the region of Latitude 53° N., which was probably still beyond the 100 fathom line. The region of moderate catches of hake had likewise extended as far in as an area fringing the good fishing in the S.W. area, while west of Scotland it had moved in among the islands and extended as a tongue into the North Sea between the Orkneys and the Shetlands, passing down across the Moray Firth. There was also a moderate concentration of hake in the Norwegian Deep Water and in the North Channel deep-water region of the Irish Sea. In the North Sea the total distribution of hake was extensive and covered the whole of the northern and middle regions, though the area of distribution lay rather over towards the eastern side, with a conspicuous wedge-like area off the north-east coast of England, from which hake were absent.

In *June, 1924* (Chart 6), the area of good fishing was extensive. It spread into the shallow water inshore of the 100 fathom line, over the Cockburn Bank, the Grand and Little Sole Banks, and off the Fastnet in the S.W. area, and "below the Bull" in Latitudes 52° N. to 53° N. beyond the 100 fathom line, and in Donegal Bay, with very heavy fishing in Galway Bay and off Slyne Head. West of Scotland the hake fishery had moved inside the 100 fathom line and extended as a tongue spreading in towards the Minches both from north and south. In the Norwegian

Deep Water fishing for hake was very poor; there was a slight concentration off the Moray Firth, while moderate quantities of hake were to be got in the greater part of the S.W. area and inshore of the region of good fishing west of Scotland. In the North Sea the distribution of hake was extensive, covering the greater part of the north and middle regions and even extending into the southern North Sea. The area of distribution shows a distinct tendency to lie over on the eastern side of the North Sea, and there is a well-marked area clear of hake extending in a north-easterly direction from the north-east coast of England.

In *June, 1925* (Chart 10), the hake fishery was very extensive, especially in the S.W. area and west of Ireland, where it covered large areas of the shoal water, particularly the Banks and the grounds off the Fastnet and the Old Head. In the deep water, fishing was only moderate on the Westward grounds, but there was heavy fishing in the deep water off the Fastnet, off the Blaskets, and below the Bull. There was heavy fishing in the shoal water in Galway Bay, off Eagle Island and Black Rock, and in Donegal Bay. There was good fishing in the North Channel, at the northern end of the Minches, and extending in from the St. Kilda grounds. In the North Sea there were slight concentrations off the Shetlands, off the Moray Firth, and in the Norwegian Deep Water, but the total area of distribution was extensive, covering the northern and middle North Sea, with a wedge-like area clear of hake off the north-east coast of England.

Summing up the June charts for the three years, the following points are to be noticed. The hake fishery is extensively spread over the shoal water areas (i.e., inside the 100 fathom line) in the areas S.W. and west of Ireland, but west of Scotland occurs as a deep water fishery off St. Kilda, which tends to move inshore, especially towards and into the Minches. The Norwegian Deep Water now gives poor fishing, while in the North Sea there are indications of concentrations off the Moray Firth, the Orkneys and the Shetlands. Hake is widely distributed, in small quantities, over the North Sea, but there is constantly present a wedge-like area clear of hake extending north-east from the north-east coast of England.

September. (Charts 3, 7 and 11.)

September, 1923 (Chart 3). On the Westward grounds good fishing was again restricted to the deep water, while "below the Bull" fishing was everywhere only moderate. There was still a good concentration of hake off Black Rock, in the North Channel deep water, and off St. Kilda, in the deep water. There was a moderate concentration of hake along the south coast of Ireland, between the Banks and, notably, on the Porcupine Bank. There was a slight concentration of hake off the Shetlands and in the eastern portion of the North Sea. The total distribution of hake in the North Sea was roughly the same as in June, except that perhaps it had extended a little further south into the Southern Bight and that no hake was to be caught apparently in the north-eastern areas of the North Sea. There was a distinct area off the north-eastern coast of England which was clear of hake.

September, 1924 (Chart 7). In the south-western area there was good fishing in the deep water, and below the Bull the fishery was clearly tending to move back into deeper water beyond the 100 fathom line. There were local areas of good fishing off the Old Head of Kinsale and in the Smalls area. Fishing was very heavy off Eagle Island, and good in Donegal Bay, while to the west of Scotland the fishery extended far towards the land among the islands. There was very heavy fishing in the neighbourhood of St. Kilda and off the Flannan Islands. There were regions of moderate fishing in the Minches, in the North Channel deep water, on the Porcupine Bank, and between the banks in the S.W. area; in the North Sea there were slight concentrations extending as tongue-like areas between the Orkneys and the Shetlands, across the Moray Firth, and also in the Norwegian Deep Water.

There was a very slight concentration in the eastern North Sea. The total distribution in the North Sea was much as in June, and again there was a clear area off the north-east coast of England.

September, 1925 (Chart 11). In the south-western area the hake fishery lay along the edge of the deep water, except for an isolated area of good fishing probably in the Smalls area, though drawn rather far to the south in the chart. There was good fishing on the outer Fastnet grounds in deep water, off the bays on the south-western coast of Ireland, in 80 fathoms and deeper, in Galway Bay, and beyond the 100 fathom line below the Bull. There was heavy fishing off Eagle Island, in Donegal Bay, on the Klondyke grounds off Inishtrahull, and especially in the deep water W.N.W. of Tory Island. To the west of Scotland the hake fishery was widely extended in the shallow water, with especially high concentrations about St. Kilda and north of the Butt of Lewis (or west of Noup Head in the Orkneys ?). Smaller quantities of hake were taken in the Minches and among the Hebrides, along the south coast of Ireland, and on the banks, in the south-western area, and on the Porcupine Bank. In the North Sea there were tongue-like areas of slight concentrations of hake extending in from the Orkneys and from the Norwegian Deep Water, while the general distribution of hake in the North Sea was much as in June, with the usual clear area extending north-east from the north-east coast of England.

Summing up the September charts for the three years there are the following points of agreement. In the south-western area the hake fishery is chiefly in deep water beyond the 100 fathom line, but to the west of Scotland has its widest distribution at about this season. In the Minches, off the south coast of Ireland and between the Banks in the south-western area, there is moderate fishing, and especially noteworthy is the presence of hake on the Porcupine Bank (Long. 14° 20′ W.). In the North Sea there is a regular tendency for regions of slightly better fishing about the Orkneys and Shetlands, in the Norwegian Deep Water, and, in 1923 and 1924, in the eastern waters of the North Sea off Jutland (Little Fisher Bank and Outer Jutland grounds). The general distribution of hake is much as in June, with a constant clear area off the north-eastern coast of England.

December. (Charts 4, 8, and 12.)

December, 1923 (Chart 4). In the south-western area the hake fishery was confined to deep water on the Westward grounds. Smaller quantities were taken along the edge of the deep water northwards to the Fastnet grounds. Inshore of the 100 fathom line there was very little hake to be caught in this area. Below the Bull there was good fishing in deep water between Latitudes 52° N. and 53° N., and off St. Kilda there was good fishing beyond the 100 fathom line. Generally speaking, nowhere in the shoal water was hake to be got in paying quantity. There were fairly good concentrations of hake in the Minches, in Galway Bay, and to a less extent off the Old Head of Kinsale in the south-western area. In the North Sea the hake were withdrawing northward, though still fairly widely distributed in the middle region.

December, 1924 (Chart 8). In the south-western area the hake fishery was confined to the deep water on the Westward grounds, in Latitude 49° N. and between 50° N. and 51° N. There was good fishing in Galway Bay and in the deep water off Eagle Island, and off St. Kilda in the deep water. Everywhere else fishing was poor or moderate. There was a fringe of moderate fishing along the edge of the deep-water areas on the Westward grounds, off the Fastnet, the Blaskets, below the Bull, and on the Porcupine Bank. In the North Sea the distribution of hake was still fairly general, with regions of slight concentration in the Norwegian Deep Water, and in the extreme north, along the edge of the 100 fathom line.

December, 1925 (Chart 12). In the south-western area there was good fishing on the Westward grounds, beyond the 100 fathom line from the "southernmost coral" (Lat. 48° 30′ N. to Lat. 50° 30′ N.). Below the Bull there was only moderate fishing, according to the chart, while off St. Kilda there was good fishing beyond the 100 fathom line. In shoal water there were local concentrations of hake in the Minches, off Dubh Artach, and in the region of the Cockburn Bank, in the S.W. area. In the North Sea the hake had withdrawn until the middle region was almost clear of hake, which was now confined to the far northern areas. There was a concentration of hake in the Norwegian Deep Water, and along the edge of the deep water to the west of it.

Summing up the December charts for the three years, the following general conclusions may be drawn. Good fishing is found constantly only in two areas: the Westward grounds, and off St. Kilda, both of which are deep-water fisheries. The charts indicate local concentrations in Galway Bay, and good fishing below the Bull and off Eagle Island is indicated by one chart in each case. Local concentrations are consistently present in the Minches, and in the deep water of the North Channel of the Irish Sea. In the North Sea there is a general tendency for a withdrawal of the hake into the northern and deeper waters. There is slight concentration in the Norwegian Deep Water.

As examples of the caution necessary in interpreting these charts, however, I may say that during a voyage to the fishing grounds below the Bull, in Latitude 52° 46′ N., depth 220 fathoms, in November–December, 1925, catches were as high as 32 boxes (cwts.) of big and medium hake for a day's work of 15 hours' fishing, and the whole voyage ("*Tamura*," Capt. Drennan) averaged 136 cwts., for 100 hours' fishing, of big and medium hake alone, not reckoning at least an equal weight of small fish. But Chart 12 indicates only moderate fishing of less than 150 cwts. per 100 hours' fishing of all classes of hake. Secondly, the figures given for the Porcupine Bank never rise above group 3 in the charts, i.e., the average catch per 100 hours' fishing is never greater than 150 cwts., yet from September to December (for example, in October, 1926), good voyages of hake are regularly landed from the Porcupine. So it is clear that while the average catches of hake in a given area at a given time may be low, individual skippers can make profitable voyages. It depends partly on the power of the ship, but perhaps chiefly on the skill of the skipper. However, it has already been stressed that statistics of this kind can only give a generalised picture, though none the less a valuable one, of the state of the fishery on any given ground at a particular time.

C. The Seasonal Distribution of Hake.

The seasonal variations in the hake fishery have been discussed in the preceding pages, where the distribution of hake, and especially of the regions of good fishing, was followed from season to season in four representative months, namely, March, June, September, and December. The seasonal variations may be summed up thus. The hake fishery may be conveniently divided into a deep-water phase and a shoal-water phase. The shoal-water phase is associated with the act of spawning in mature hake and in immature hake with a general inward drift of oceanic organisms. These points are fully discussed towards the end of this paper. The shoal-water phase is relatively short in its duration, but the deep-water fishery lasts all the year round, apparently because the spent mature hake return to deep water in numbers sufficient to replace those ripening fish which move into shoal water to spawn, so that the hake shoals tend to be kept sufficiently dense to permit of a continuous profitable fishery on the edge of the deep water. This applies especially to the grounds below the Bull; on the Westward grounds hake is said to be scarce and fitful between the months of August and December. In December and January the hake "set in" on the Westward grounds, and from this time the hake trawlers usually fish those grounds, if the season promises well.

The absence of hake in steady quantities on the Westward grounds, where the slope down to the depths of the Atlantic is very steep, between the months of August and December, has a special explanation, which will be discussed in the next section of this paper.

The boundary line between the deep-water phase and the shoal-water phase of the fishery may be conveniently put at 100 fathoms, though this is an entirely arbitrary depth, and subject to great variation in different circumstances, and especially in different regions.

The hake's invasion of shoal water coincides with the time of spawning, though the hake need not come in to shoal water to spawn, for on the Morocco and Cape St. Vincent grounds, which are worked shortly before, and during, spawning, the depths fished are as great as 200 fathoms. Moreover, Schmidt (1908) shows that very young fry of the hake may be taken in mid-water over 1,000 metres depth, so that spawning can, and actually does, take place over deep water.

Clark (1923) writes that " it is thought that the fish spawn in midwater, at least so far as our evidence goes, for ripe fish are constantly being taken in the trawl, which fishes at the bottom, while records of running fish are comparatively rare." Observations on the hake grounds " below the Bull " confirm this, for in many thousands of hake examined at all seasons of the year, I have only found two or three fish, in the deeper water, with roes in the last stage of ripeness, i.e., containing large transparent eggs. But in this case I consider that ripe fish usually run into much shallower water (60–80 fathoms) to spawn, and in the south-western area spawning certainly takes place on a large scale in water 50–60 fathoms deep (see, however, section F). Schmidt's observations (1908), however, make it practically certain that spawning also takes place over deep water.

The manner in which mature hake move in to the spawning areas is discussed in section F, on the monthly cycle in the hake fishery. The time of the invasion is very variable ; during the past three years, the arrival of the spawning shoals at Melville Knoll, off the Scilly Islands, which, perhaps, marks the annual climax of the hake fishery in the south-western area, has varied between three months. Reasons will be given later in this paper for believing that the invasion of shoal water is very closely associated with the physical conditions, and especially the temperature of the sea, which likewise vary from year to year. This question is further discussed in section O.

The spawning season of the hake, which is usually accompanied by the inward migration of mature fish, falls later in the year as the region lies further north. The time of spawning-concentration of the hake shoals, and the inward movement, therefore passes from south to north in a wave, which has deceived many people into believing that there is a vast migration of hake from the Atlantic off Morocco northwards as the season advances. In other species of fish, for which a similar great migration has been suggested, for the same reason, this has been disproved by the demonstration of local races confined to a certain region. The usual course of this northward wave is sufficiently described by le Danois (1921) ; it is also clearly indicated by Schmidt (1908). It closely resembles the northward drift of Atlantic oceanic organisms, such as salps (see section M of this paper), and is possibly linked to the same fundamental physical factor.

There is a distinct tendency for a northerly movement in the hake fishery, in the spring months, along the edge of the deep water. Hake " set in " at the Westward in about latitude 49° N. in December and January, and tend to move in a northerly direction towards the Fastnet, though the movement is indefinite, and rather takes the form of a succession of waves. The same is true of the fishing grounds below the Bull. For example, in March, 1926, the hake fishery moved northward in the space of three weeks, from Latitude 52° 20′ N. to Latitude 53° 20′ N., where the fish thinned out, or " took off."

The northward movement of spawning concentrations is of great practical

importance to the industry. For instance, in December, when the hake on the home grounds are still spent fish, and, generally speaking, still scattered, so that fishing is rather poor, those off the Morocco coast-banks are massing for spawning. It often pays well to send trawlers 1,500 miles down to Cape Cantin, or Cape Ghir, or to Cape Vincent, at this time of the year, but the hake fishery in regions where the water deepens very suddenly is notoriously uncertain, and unfortunately, also, in recent years the southern fishery has been more or less of a failure, while the Morocco hake, which has coarser flesh than that of northern fish, does not fetch such good prices.

Table II gives at a glance the typical course of events on the more important hake grounds. In March, there is already a tendency for the hake to set in to the shoal water off the Fastnet, and it is also in March that the hake fishery is at its best in Biscay, so that it may then be worked by British trawlers (see Chart 9). In June, the shoal water fishery is at its height in the south-western area, but, in 1925, I found spawning hake as early as March off the Old Head of Kinsale, and as late as July off the Hook. In June, however, the shoal water phase is only beginning in the waters west of Scotland. In September, the shoal water phase is at its height to the west of Scotland, and in the Irish Sea, while in the south-western area it has practically passed, so that the chief fishery there is now in deep water. Finally, by December the hake fishery is everywhere confined to deep water. The penetration of hake into shallow waters is discussed in section O.

TABLE II.

The general course of the hake fishery, as illustrated by a study of the distribution, in four typical months, on the principal grounds.

	Deep water phase.	Shoal water phase.	
March	Westward grounds. Outer Fastnet grounds. Below the Bull. St. Kilda. Norwegian Deep Water.	?Inner Fastnet grounds.	
June	Westward grounds. Outer Fastnet grounds. Below the Bull. St. Kilda.	The Banks. Melville Knoll. Old Head. Galley Head. The Hook. West of Ireland.	S.W. Area.
September	?Westward grounds. ?Outer Fastnet grounds. Below the Bull. Porcupine Bank. St. Kilda.	Galway Bay. Donegal Bay. Irish Sea. Clyde. Dubh Artach. Skerryvore. Minches, &c.	W. of Ireland and W. of Scotland.
December	Westward grounds. Below the Bull. St. Kilda.		

Yet one is often told that in earlier years, especially prior to 1903, when the deep water hake fishery beyond the 100 fathom line was first discovered, it was never necessary to make long voyages to the deep water, and that, then, hake could

be taken all the year round in shoal water. In the mud off the Smalls, for instance, hake could be taken in good quantity, summer and winter, by the Milford trawlers and smacks.

It is true that almost all the earlier writers refer to seasonal changes in the abundance of hake. To judge from the comments of Rondeletius (1554), and Aldrovandus (1638) the true hake was certainly included among the several possible fish of which Aristotle wrote " we infer that it hides over a lengthened period of time from the fact that it is only caught at long intervals." Rondeletius (1554) who was clearly writing about the true hake, says that fishermen can catch hake at almost all times ; but Aldrovandus (1638) plainly indicates that the hake is an oceanic fish which moves in to the coast from deep water.

Pennant (1769) says that, on the Nymph Bank, immense quantities of hake appear twice a year, and Duhamel du Monceau (1772) says that, presumably on the coast of Brittany, hake are most abundant from mid-April to mid-July. Risso (1826) writes that, in the Mediterranean, the fishery for hake is all the year round, but Fleming (1828), Storer (1838), Day (1880), and Cunningham (1896) all imply a seasonal change in the appearance of hake. Day writes definitely that " in the winter, it is most commonly taken in the deeper water."

It is clear, therefore, that a seasonal periodicity in hake has been known from the earliest times, but it is not possible to believe that the changes in the fishery were so profound as they are at the present time. When Day spoke of " deeper water " he could not have meant the depths, namely from 120 fathoms down to 300 fathoms and deeper, at which hake must be sought in winter at the present time.

Now, it is very interesting to note that there are localities, at the present time, where hake may be taken in small quantities, all the year round. A good example is the deep trough which runs down to the latitude of the Calf of Man from North Channel. Charts 1–12 indicate only slight concentrations in this region, but in December, 1925, a good voyage of hake was landed from the Peel Deep, with St. John's in the north, at Liverpool. In the deepest parts of the Clyde basin (Inchmarnoch), in the deep Scottish sea-lochs, in the deep troughs and pits east of Barra Head and north of Tiree, and off South Rona in the Minches, and in the Norwegian Deep Water, hake is said to be present all through the winter. This distribution of hake in winter, with the fact that the great bulk of hake landed during the winter has been caught beyond the 100 fathom line, points to a depth-migration, in which, during the winter, hake tend to seek the deepest water available. This theory of a depth-migration in hake will be discussed more fully in a paper in course of preparation, but I may say that, in mature hake at least, the depth of the fishery is closely associated with the state of exhaustion or recovery of the sexual organs of the hake, and with the accompanying changes in weight of the liver and flesh. This may be inferred from Figure 11.

It is not at all unlikely that the depth-migration, which seems essentially associated with the ripening and exhaustion of the sexual organs in the hake, may tend to vanish in old fish. Belloc (1922) notes that old females (which he considers upwards of 7 years old) have a diminished faculty of reproduction, and that many of these old fish were found with ovaries which had not ripened after spawning. This has also been my experience. Many " jumbo " hake have been dissected, in which the ovary has remained collapsed, with a thick fleshy membrane, and in which the eggs have remained small. Brown pigment is often found, also, in the lamellæ. It seems, then, that there is a loss of sexual activity, and even degenerative changes in the ovaries of old hake, and this would tend to be associated with a disappearance of the impulse manifested in the depth-migration. In the days when trawling was less intensive, a far greater number of hake would survive to this stage, in fact, in sufficient numbers to supply a small fishery all the year round. This speculation will be tested further if an opportunity is offered.

As far as the Smalls area is concerned, perhaps the slight concentrations represented in Charts 1, 4, 7, 8, 9 and 11 are the last indications of the former state of affairs. But whatever factors may have combined to mask a depth-migration formerly, we must believe that it was present, none the less, in sexually active hake at least, and is an essential part of the annual course of changes in the life of the fish.

Depth-migrations are known in other fish. Dakin (1908) gives this very significant note on the Lump-sucker. "Cyclopterus appears in the shallow water round Helgoland, often adhering to the rocks, and left high and dry by the tide, during the spawning season in spring only. In May and June it begins to disappear, and in summer seems to have left for deep water, since very few are caught. The fish kept in the aquarium, though thriving well in spring, almost all die as the time approaches when they should normally leave for deep water."

Schmidt (1907) states that the Iceland cod are usually found in shallow water only in early spring during spawning. In the summer they are chiefly found in deep water. The same author (1906), in describing how rarely ripe specimens of the common eel are found, even among the silver eels, migrating to the open sea, concludes by saying "it seems that the eel must go into great depths before it spawns." He compares this life history with that of the halibut, fully grown specimens of which were only found in deeper water, and he suggests that the halibut also must descend to great depths before spawning.

Cunningham (1891) describes how ripe conger-eels, when kept in captivity, show signs of illness and emaciation, and die; the natural spawning place of the conger is at depths of more than 1,000 fathoms.

D. The Seasonal Changes in the Quantity of Hake Caught in Different Regions.

In order to discuss the annual changes in the actual weight of hake caught on the fishing grounds, the latter have been divided into regions, which, in my opinion, correspond as nearly as possible with the natural hake regions. These regions are shown in Chart 13.

Region 1 includes two deep-water hake grounds, "to the westward" (Lat. 48° N. to Lat. 51° N., roughly), and the outer Fastnet grounds (Lat. 51° N. to Lat. 52° N.). Northward of Latitude 49° 50′ N., and especially from Latitude 50° 30′ N. to Latitude 52° N., the deeper ground (deeper than 170 fathoms) is overgrown with "coral" (*Lophohelia prolifera*), and requires especial skill and long experience to work successfully. The region also includes the shoal water grounds inshore of the 100 fathom line, which include "the Scillies" (Melville Knoll and the adjacent areas), "the Banks" (Cockburn Bank, Jones Bank, Labadie Bank, &c.), the Smalls area, and the shoal water grounds off the Blaskets, Skelligs, Bull, Fastnet, Galley Head, Old Head, Minehead, and the Hook.

Region 2 includes the deep water grounds "below the Bull," i.e., in which a certain number of miles is run on a course set at Bull Rock Lighthouse. These grounds lie roughly between Latitudes 52° N. and 53° 40′ N. The region also includes the Porcupine Bank, Galway Bay, and the deep and shoal water grounds off Eagle Island and Black Rock. The grounds below the Bull are fine sand from Latitude 52° 10′ N. to about Latitude 53° 20′ N., between depths of 80 and 170 fathoms, but inshore of the 80 fathom line the ground is very rough, and in Galway Bay itself there are only certain areas where the ground is clear enough to trawl over without using "bobbins." In the deep water north of Latitude 53° 40′ N. the bottom is rough with stones and coral, and the same is true of the Porcupine Bank in depths greater than 170 fathoms.

Region 3 includes the whole shelf area west of Scotland, but it is well known that the vast bulk of the hake from this area is caught in the deep water off St. Kilda. Hake caught at "the Kildas," however, may actually have been taken at

a considerable distance, up to 30 miles, from the islands. There are also deep water fisheries for hake north of the Butt of Lewis, west from Barra Head, and W.N.W. from Tory Island.

Region 4 includes the Irish Sea, the North Channel, and the Firth of Clyde; it is considered separately because there are some peculiar features in the presence of hake in this area, especially in the slight concentrations of hake which are present in the deep water of the Irish Sea and North Channel all the year round.

Regions 5 and 6 are divisions of the Ministry's statistical area "Northern North Sea." Region 6 has been considered separately because it includes the Norwegian Deep Water.

Region 7 is the Ministry's statistical area "Middle North Sea." The Statistical Section has supplied me with the calculated average catch of hake per 100 hours' fishing by British trawlers landing in Great Britain for each of these areas. The data are available for 1923, 1924, and 1925. They are published in full in the Appendix, Table V.

In Figure 3 are drawn curves representing the mean monthly catch per 100 hours' fishing in each area. The means are of the years 1923, 1924 and 1925. Only one of the North Sea regions, Region 5, is drawn in Figure 3.

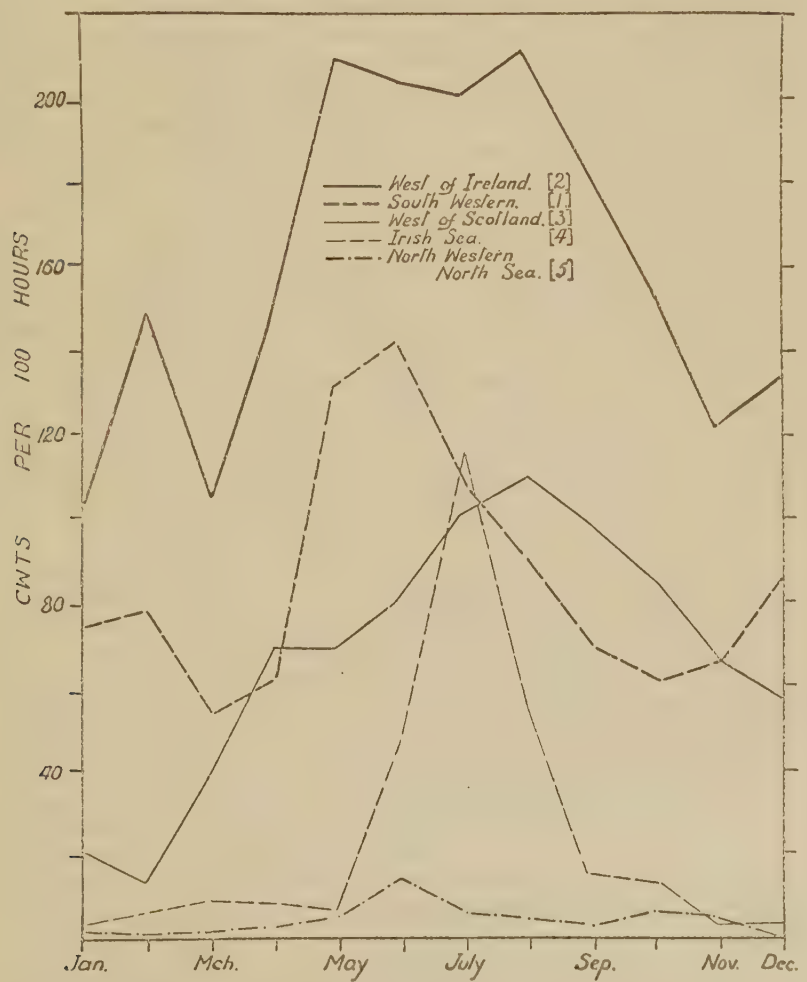


FIG. 3.—Mean monthly catch of hake in cwts. per 100 hours' fishing, in each of the areas 1 to 5 in Chart 13. Means for the period 1923, 1924 and 1925. Data in Appendix, Table V.

The curves show, in the first place, that, generally speaking, the time of best fishing lies later in the year as the latitude of the region lies further north. This has already been discussed. In the curves, the best fishing for the region 48° N. Latitude to 52° N. Latitude lies in June, for the two regions, between 52° N. Latitude to 54° 30′ N. Latitude, and the Irish Sea area (Regions 2 and 4) in July, and for the west of Scotland area in August.

It is seen also that on the average the best fishing is to be found in the West of Ireland area, and this is well known as the most reliable hake ground and one in which hake are usually present all the year round, at changing depths and in different localities. In this connection, however, it should be pointed out that the size of the region, and especially that proportion of it which lies along the edge of the deep water, must have a great effect on the average catch as calculated for the whole area. In Region 2, a relatively large proportion of the area consists of deep water hake grounds, in which hake is caught all the year round; in Region 3, a relatively small proportion of the area consists of deep water hake grounds, these being confined, as has already been stated, chiefly to the St. Kilda grounds.

The Irish Sea region is remarkable because, except during the summer months between June and August, there is very little hake caught, on the average. During those months, however, catches become quite high, and it seems clear that there is a definite invasion of the Irish Sea area.

It is very likely that this migration takes place from the west of Ireland area, viâ the north of Ireland. The tendency of the hake to move northwards during the spring months has been noted, and the hake certainly penetrate into the Irish Sea via the North Channel. It is noticeable, in Figure 3, that the peak in the Irish Sea catches coincides with a slight drop in the West of Ireland catches, and this is true for the years 1924 and 1925, as may be seen in the Table V in the Appendix.

The three North Sea regions are remarkable because, in spite of the vast area of trawlable ground, very little hake is landed from them. As Figure 3 shows, catches are never high, and, on the average, very low. The North Sea regions rarely contribute more than 4 per cent. of the total quantity of hake landed in the British Isles, and only yield catches comparable with the West Coast catches for a short period during mid-winter, in the deep water off the Norwegian Coast. The penetration of hake into the North Sea, however, has great theoretical interest, and it will be discussed at some length later in this paper.

A very characteristic and constant feature of the hake fishery is a double crest in the curve for the average catch per 100 hours' fishing, as revealed by the statistics. There is, apparently, beside the period of high catches in the summer, a period of high catches in mid-winter. This is well shown in Figure 4, which shows the mean monthly catch of all classes of hake during the years 1923, 1924 and 1925 in Region 1, Chart 13. The double crest is also indicated for the mean of all regions, in Figure 1 and in Figures 4, 5, 7, and especially well in Figure 3, which shows the mean monthly catches for the years 1923, 1924 and 1925.

The essential difference between the winter increase in catches and the summer increase in catches is clearly shown when the percentage of big hake is plotted on the same graph. In Figure 4 the mean monthly percentage of big hake for the same area is represented by the pecked line. The summer period of good fishing is associated with a sharp rise in the percentage of big hake, due to the spawning concentrations, whereas the winter period of good fishing is not accompanied by any well-marked increase in the percentage of big hake. In other words, it is a concentration of all classes of hake.

In the preceding sections I have described the seasonal changes in the hake fishery, and how, in winter, the hake moves outwards to the edge of the deep water, in the neighbourhood of, and beyond, the 100 fathom line. The hake, therefore, of all classes, become concentrated in the deep water, and this accounts for the mid-winter rise in the quantity of hake caught in unit time of fishing. This may

be inferred from Figure 13, in which the catches of hake, throughout the three years 1923, 1924 and 1925, in the statistical area " S.E. of Ireland " (S.E. Chart 13), are compared with the catches of hake for the whole south-western area. The area " S.E. of Ireland " lies wholly in the shallow waters within the 100 fathom line, and Figure 12 shows that hake are almost absent from the shallow water area during the mid-winter months. It is just at this time that the catches in the whole south-western area rise somewhat, and since " S.E. of Ireland " may be taken as a region representative of what happens in the shallow water generally, it will be understood that these hake, on their return to deep water, must appreciably reinforce the numbers of hake there.

The secondary winter peak also coincides roughly with the time of spawning of the hake's principal food, the blue whiting, and in the waters to the west and north of Scotland at least, according to my observations, the spawning concentrations of blue whiting may have an important effect in causing feeding concentrations of hake and therefore heavy local catches. Since the blue whiting spawns over deep water (1,000 metres, according to Schmidt), this may be a factor of importance in causing an increase in catches at the time of the deep water phase of the hake fishery.

But if Figure 13 is compared with Figure 4, it is seen that the increase in the quantity of hake actually landed is very much less than the increase in catches per 100 hours' fishing. This may also be seen in the statistics for the area West of Ireland (Region 2, Chart 13). Not only are the mid-winter increases in catch per unit time, shown especially well in February, 1923, and February, 1924, entirely without effect on the landings of hake, but the drop in landings in winter is relatively much greater than the drop in catch per 100 hours' fishing.* There are obviously other factors at work to cause the low winter landings from these areas, and, therefore, for the whole fishery, as shown in Figure 2.

The factors which are responsible for the relatively low landings in winter, as compared with the landings in summer, may be discussed under two headings, mechanical factors and biological factors.

Mechanical factors.

(*a*) The most obvious explanation for the diminishing landings at the close of the season is that the great summer fishery reduces the quantity of hake in the sea. While an intensive fishery probably does remove a considerable percentage of the stock, the regularly repeated rise and fall in the annual course of the fishery through a series of years shows that this is not a significant factor in causing the winter scarcity, which is rather of the nature of a natural fluctuation consequent upon migrations of the fish.

(*b*) Bad weather during the winter often interferes with fishing for days in succession, and this undoubtedly contributes to the low winter landings. The effect of bad weather is often rather indirect than direct, in that skippers are unable to keep on the grounds they have found best, are unable to tow the trawl except in one direction, usually head to wind, in very bad weather, and, finally, a heavy swell causes the trawler to jerk at her gear, so that there is serious risk of the net being badly split.

Biological factors.

(*c*) In a later section the daily variation in the quantities of hake caught will be described. Skippers say that as soon as darkness falls the hake " take off " the bottom, and are no longer to be caught in the trawl until shortly before daylight, when they apparently return to the sea-bottom. During the winter

* See Figure 5.

months, therefore, when the days are short and the nights long, one would expect less hake to be landed, since each voyage during the winter represents less fishing time than voyages of corresponding length in the summer.

(*d*) During the winter the hake fishery is confined to the deep water, and consequently can only be exploited by the larger type of steam trawler, whereas, during the summer shoal-water phase of the fishery, hake are to be caught in quantity by all types of trawler. Consequently, hake will be landed by a much greater number of ships, with a resulting bigger total than when the larger trawlers alone are fishing for hake.

(*e*) Perhaps the most important factor in causing seasonal fluctuations in catches is the varying concentration of the hake shoals. It is obvious that each haul will take hake in greater or lesser quantity accordingly as the hake shoals are massed or scattered. The chief factor which brings fish together in a small area is spawning, and at spawning time hake are densely congregated and catches are very high.. This process is described in the next section. The June and September

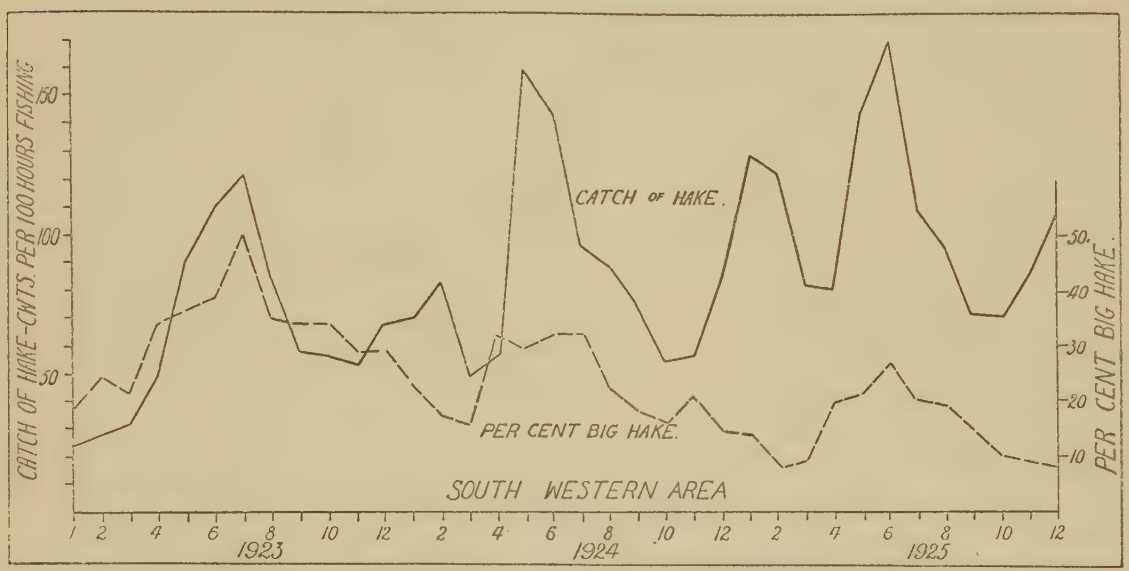


FIG. 4.—Mean monthly catch of hake, in cwts. per 100 hours' fishing, in the South-Western area (Region 1, Chart 13), for the years 1923, 1924 and 1925, with the mean monthly percentage of big hake during the same years. Data in Appendix, Table VII.

charts in the series of Charts 1–12 show that, at this phase, there are very high concentrations of hake, as shown by the high group-numbers on the charts. This plays an important part in causing the high summer landings; but the winter concentration of hake in the deep water may be, on the average, not greatly less (see Figure 4).

(*f*) This leads on the final factor in the decline in the landings of hake in winter. Schmidt (1909), writing of the hake, says: "To the West and South of the British Islands, where the slope of the bottom is steep, the distances horizontally from shallow to deep water are but short, and it is an old experience from my investigations at Iceland, that fishes, for example, the cod, which are otherwise bottom fishes, may well lead a distinctly pelagic life in large quantities in the neighbourhood of such steep slopes, living exclusively on pelagic organisms. I think it is not improbable that the hake may live in large quantities beyond the 1,000 metre line (500 fathoms) and reproduce there . . . ." He adds in a footnote: "I have several times taken large specimens in August-September, 1909,

S.W. of Ireland, which were living pelagically over considerable depths, e.g., 500 metres, even in the slow-moving young fish trawl."

I consider it highly probable that hake actually do live a life in mid-water over the great depths. In a later section I shall show that the hake is entirely independent of the sea-bottom, feeding upon a group of oceanic mid-water* fishes and squids. Its principal food during the deep water phase, the blue whiting (*Gadus poutassou*), can live, and breeds exclusively, beyond the 500 fathom line. The well-marked vertical movement shown by hake, in which the fish tends to sink and lie on the bottom by day, and leaves the bottom at night, is paralleled by many other fishes and other large organisms which pass their lives in mid-water over the great ocean deeps. Murray and Hjort (1912) give many examples, and Taning (1918) publishes data which shows that many small mid-water luminous fish (Scopelids) have a distinct up and down movement in response to the changes between day and night, though this author is cautious of accepting his results as proof. The statistics I have brought forward show that, though the hake withdraw almost completely to the edge of the deep water, where the slope of the

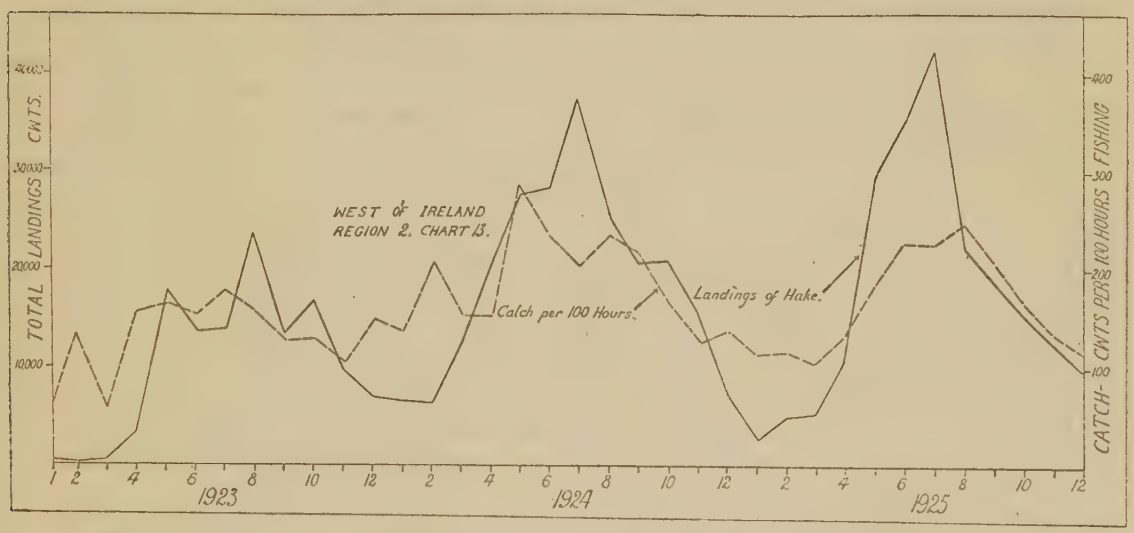


FIG. 5.—Catch of hake, in cwts. per 100 hours' fishing, in the region "West of Ireland" (Region 2, Chart 13), compared with the landings of hake from that region during the years 1923, 1924 and 1925. Data in Appendix, Table VIII.

bottom becomes very steep, so that the hake become concentrated and the catch in unit time rises sharply (Figure 4), there is no distinct improvement in the landings; and while factors (*a*) to (*e*) may serve to account for a considerable part of the decline in the quantity of fish landed at this time, I consider that a great part of the hake stock is then living over deep water clear of the continental shelf.

Goode (1884), writing of the closely allied American species of hake, says that "it inhabits the middle depths of the oceans, on the outer edge of the continental slope, and it comes to the surface to feed. Its teeth are sharp, its mouth large and powerful, and its form lithe, muscular, and adapted to rapid locomotion."

This may account for the well-known habit of hake, especially in the early months of the season (January to April and May) on the Western grounds, where the sea bottom sinks from 100 to 1,000 fathoms in ten miles in some areas—namely, "taking off." The fish may disappear at a day's notice from a given locality, so that catches drop to a low level. This is the experience of every skipper. For instance, in May, 1925, on the deep water grounds off the Blaskets, Lat.

* By "midwater" is here meant the region lying between the bottom and the surface.

51° 45′ N. Long. 11° 40′ W., catches fell from 20 score of big and medium hake per haul to 6 score per haul in two days. When this happens, of course, the ships scatter, and feel along the edge of deep water, according to the experience of their skippers, until another point is found where the hake have " set in " into trawlable water.

The hake should probably be regarded as a fish in which the habit of living and feeding in mid-water,* occasional in the Cod, has become permanent ; though, on the continental shelf, the diurnal vertical movements, characteristic of mid-water organisms, bring the hake to the sea-bottom within reach of the trawl (see section G).

E. The General Distribution of Hake.

According to Collett (1896), the hake is " abundant in the Mediterranean and on the S.W. coasts of Europe. It is taken in the eastern as well as in the western Mediterranean, and the British Museum possesses a specimen from the Bosphorus. It occurs in Grecian waters, and abounds about the coasts of Italy, to the extremity of the Adriatic, and around Sicily . . . It is found off the coast of Sweden, though in small numbers, off Bohuslan. It has been taken at the Lofoten Islands in Latitude 68° N." Smitt (1892) says that " hake occurs throughout the North Sea ; it is extremely plentiful at a few spots on the coast of Brittany and the south-west coast of England and all round Ireland, but it is said to be rare to the north-west of Scotland ; off the Faröe Islands it is not known." He says that it seldom penetrates the island belts at the entrance to the Baltic, but Ehrenbaum (1910) says that the hake finds its way into the Skagerak and Cattegat, and, very occasionally, into the western Baltic.

From the fisheries point of view, the northern limit of hake is Lat. 62° N. (see Charts 1–12). The most northerly grounds worked for hake alone are in the deep water north of the Butt of Lewis, in the Norwegian Deep Water, in winter, and in shoal water off Noup Head (Orkneys) in summer, in 50 fathoms, which is probably the most northerly spawning ground. The southern limit of the hake has probably never been reached, indeed, there is strong ground for believing, with Le Danois (1921), that the hake may have a continuous distribution down to the Cape of Good Hope, in which case the Cape hake would be a simple variety of the European hake. It is very interesting to record that Capt. Lathom, of Fleetwood, who saw quantities of Cape hake landed while he was in South Africa on war service, could see no obvious difference between those hake and the hake landed from our home grounds. Local varieties of hake have been fairly frequently reported (for example, Lowe 1843, Pietschmann 1906), and in a future paper I hope to show statistically that there may be racial differences between hake from quite closely adjacent areas.

British trawlers work regularly as far south as Cape Ghir, on the Morocco coast, and occasionally even as far south as Cape Juby (Lat. 28° 10′ N.). The easterly limits of the fishery seem to be the Skagerak, in the northern areas, where there is a fishery, principally in the summer months (Henking (1905), Smitt (1892), and statistics published monthly in " Der Fischerbote ") ; and, in the Mediterranean, the most easterly fisheries are those off Alexandria and Port Said (Annual Reports of the Fisheries of Egypt).

Hake are absent, or very rare, at Rockall and Faroe, and apparently also from the system of banks running west and south from Faroe to Rockall (Pawsey and others (1922)). Small quantities are given in the statistics as landed from Faroe, but men with whom I have sailed have never seen hake caught at Faroe, and much the same can be said of Rockall. It is quite absent from Iceland.† Ehrenbaum (1910) remarks that the English and German statistics show small catches of hake

* By " midwater " is here meant the region lying between the bottom and the surface.

† Three hake, together weighing 25 lbs., have recently (Oct., 1927) been landed at Grimsby. These fish are said to have been caught off Iceland, in Faxe Bay.

at Faroe and Iceland, and is in doubt as to the true explanation, but Edser (1925) points out that catches are allotted to the area in which over 70 per cent. of the fishing has been done. An Iceland boat, for instance, which might stop for a "dip-haul" in waters near home, would land a box or two of hake, which would be referred, statistically, to Iceland. This source of error, has led Le Danois (1921) to go as far as to say that the "hake fishery . . . around the Faröes takes place chiefly in October."

As charts 1–12 show, hake is absent from the greater part of the English Channel, from the southern North Sea, the Bristol Channel, from the St. George's Channel, and from the less oceanic parts of the Irish Sea. One is told that there is no hake to the northward of the margin of the "white weed" area, where the bottom is covered by the fragrant polyzoan *Flustra*; the margin of the "white weed" is roughly indicated by a line drawn from the Saltees Islands to the Smalls Light.

There is no reason to believe that the area of distribution of hake has altered in recent years. For example, in the English Channel, there were formerly great quantities of hake, which were caught and landed at Plymouth. Boyton (1908) writes that "some 30 years ago, hake were extremely plentiful in the western part of the English Channel, and the boys on the smacks used to catch them with hand lines . . . At that time hake used to be brought into Plymouth market and piled in great heaps on the flags. . . . Very few, comparatively, are now to be seen in Plymouth market or anywhere in the west."

Charts 1–12, based upon the data at the disposal of the Statistical Section, show that small numbers of hake are still present in the western portion of the English Channel. But when there has been a very great decrease in the total hake stock in the whole south-western area (and this is all too surely the case) this decrease must make itself felt most acutely at the margins of the area of distribution. This applies equally to the North Sea, where great quantities of hake could be taken off Heligoland in earlier years, though they are rarely seen there now. But there is no reason to believe that there has been any drastic change in the area inhabited by the hake. Similarly, the appearance of baby hake in great numbers off Plymouth in 1923, as discussed by Clark (1923), was one with the appearance of vast quantities of small hake in the south-western area as a whole, which became especially noticeable at that time, and which has been such a striking feature of the fishery since.

Charts 1–12 show further interesting points. They apparently show the rise of two important fisheries, the fishery off St. Kilda, and the fishery in the Norwegian Deep Water. The St. Kilda fishery first appears in Chart 4, in December, 1923. Now, I am told that, while the deep water grounds west of Barra Head and off the Flannan Islands have been occasionally worked for many years by a few skippers, the exploitation of St. Kilda as a hake ground on the large scale is of quite recent date. At the present day, according to a letter written to me in March, 1926, by Mr. E. Towne, 90 per cent. of the hake landed at Fleetwood is caught at St. Kilda, and when I was at St. Kilda, in January, 1926, almost the whole of the Fleetwood deep-sea fleet was working there. The St. Kilda grounds have probably played the chief part in the rise of Fleetwood to the position of the most important hake-port.

Howell (1921) gives a very interesting note on the St. Kilda hake fishery. In 1920 and 1921, apparently, hake were not to be caught south west of St. Kilda, but were caught in quantity off the Flannan Islands. This suggests a shifting of the area of best fishing; but such a shifting is the general rule on the Westward grounds and below the Bull, when the fishery is never exactly the same from one year to another. In any case, in January, 1926, the best fishing for hake was south-west off the St. Kilda Islands, in 170 fathoms, where it was prior to 1920, on Howell's evidence.

On the northern grounds, however, hake seems to be especially liable to shift both its depth and its position in a more or less irregular way, while still showing the general movement into deeper water during the winter months, and into shallower water during the summer months.

In a similar way the deep water of the Norwegian Channel has only been exploited comparatively recently. I am told that west coast skippers, used to working deep water, went up to Aberdeen in 1924, and that one of these caught 250 score of hake for a week's work in January, 1925, a voyage which would be considered very good on the west coast grounds. The time of good fishing in the Norwegian Deep Water is short, lasting only two or three months, though a good trip of hake was landed from there at Hull as late as Good Friday week, April, 1926. As Charts 1–12 show, in June there is only a low average concentration of hake in the Norwegian Deep Water.

The charts also show interesting variations from year to year, which are most easily seen in the North Sea. For example, in September, 1923, there was a comparatively considerable concentration of hake in the eastern portion of the

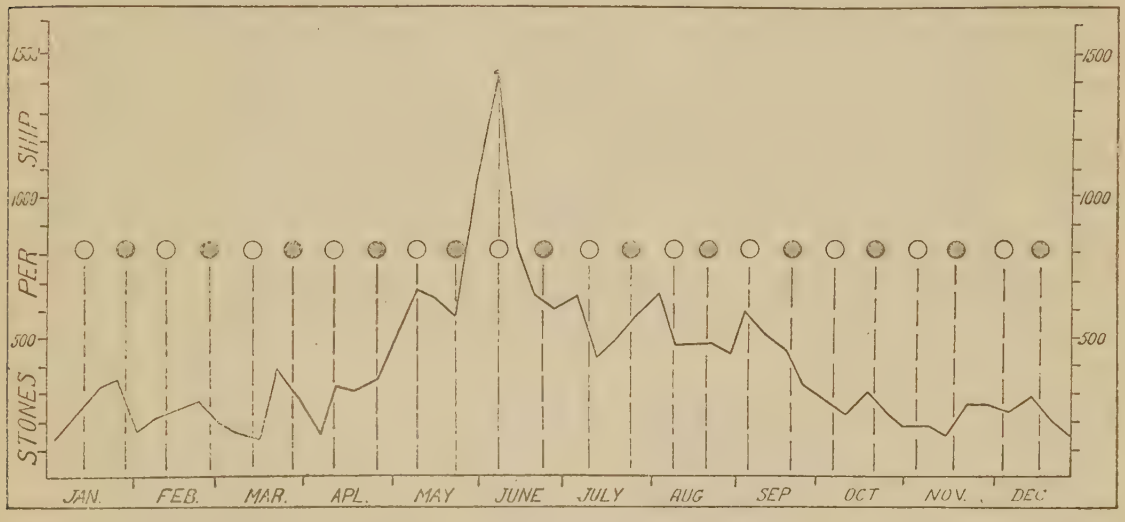


Fig. 6.—Weekly mean landings of big and medium hake, in stones per ship, at Cardiff during the year 1922. The times of full moon are also shown. Data from the "Fish Trades Gazette," Appendix, Table IX.

North Sea, which is also indicated in 1924, but is absent in 1925. Similarly, in 1925, the typical winter distribution of hake, when they are confined to the extreme north of the North Sea, had been reached early, in December, whereas in 1923 and 1924 this distribution occurred in March.

F. The Monthly Change in the Hake Fishery.

The account of the annual change in the hake fishery was based on monthly data supplied by the Statistical Department, but this masks what is apparently an important monthly cycle. It is well known in the industry that, during the summer months, the catch of hake fluctuates at much shorter intervals than graphs drawn from monthly data seem to indicate. Indeed, while the general level of the landings is distinctly higher than the winter landings, the bulk of the hake which make the monthly totals in the summer so high may be landed in the course of a few days, causing gluts, "which," writes Commander Lawford in the "Times" of September 5th, 1926, "are one of the principal causes of the shocking conditions in which the industry finds itself to-day."

It is said among the trawlermen that times of glut or times of good fishing occur regularly at intervals which they rather vaguely associate with either the "rising tides" or with the phases of the moon. Hence it has seemed worth while to examine the annual course of the fishery by means of weekly data, to find whether any definite rise and fall in the catches occurred, and if so, whether they bore any relation to the moon's phases.

Weekly figures of hake landings available for this purpose are published in the "Fish Trades Gazette." The landings at Cardiff, as there given, are used for several reasons. Firstly, Messrs. Neale & West's trawlers work almost exclusively for hake, so that one can assume that, with the exceptions noted in the "Gazette," every ship landing at Cardiff has been working for hake throughout its voyage; secondly, these ships make voyages of approximately equal length, thus removing the necessity of correcting for the number of days' fishing; and thirdly, the fleet consists of trawlers all of approximately the same size and power, all of which use the same type of trawl. The landings of large and medium hake alone are dealt with, as small hake apparently do not show a monthly variation.

The chief disadvantage in using the Cardiff landings lies in the fact that Messrs. Neale and West's ships are known to work in the deep water, almost entirely throughout the year, and the monthly cycle about to be described is more usually a phenomenon associated with the shoal water phase of the fishery. (Table II in the text.) The exception is the annual fishery off the Scillies, 80 fathoms, which is worked by the Cardiff men, and is responsible for the very high crest which appears in each of the years examined (Figure 6 and Appendix, Table IX). Hence the "gluts" revealed by the Cardiff landings are probably much smaller in range than those which the hake fishery, as a whole, experiences, with the exception just mentioned. None the less, the Cardiff figures show a fairly definite periodicity, though, having in mind the unsatisfactory nature of the statistics used, this note should be regarded as no more than an indication of what might be done with more complete data.

The "Fish Trades Gazette" publishes the landings of hake, in boxes or kits, usually for the first four days of each week, though often some of the days, and occasionally a whole week, are missing. From these figures have been obtained, for each week, the mean daily landings, in stones, for that week, per ship landing. Where the week's landings are fairly uniform, this mean is plotted for a point midway between the days which supplied the data; but where the successive days show a definite tendency to rise or fall, the mean has been plotted for the day on which landings are highest Since, in the vast majority of weeks, landings are given only for the first four days, the mean must be plotted for a point not more than 1½ days on either side of the mid-point of the week's landings. These figures are given in full in Appendix, Table IX. For the present purpose any definite "peak" in the landings is counted as a glut, and the whole year is considered, since, with these data, there is no justification for distinguishing between regular and irregular fluctuations, nor between crests shown during the summer and during the winter. In Appendix, Table IX, the crests of "gluts" are marked in *italics*, and where a crest is formed by two equally high landings in successive weeks, both have been counted as "gluts," as the table shows. The phases of the moon are also given.

Figure 6 shows the course of the fishery in 1922, as deduced from the data just discussed. There seems to be a fairly regular periodicity in the fluctuations, especially from March on to August. During the rest of the year, when the landings, on the whole, are low, there is a less definite variation, which may be due to an actual disappearance of the rhythm, or to a masking due to interference by bad weather. The crests of the curve tend to lie near full moon in each case.

Figure 7 is a graph drawn for the means of the years 1922–1925 inclusive. The figures on which it is based are given in the Appendix, Table X. They are obtained from the same " Fish Trades Gazette " data as have been used for drawing up Table IX. The means of the landings of big and medium hake, in stones per ship, at full moon and new moon, with a two-day allowance for the fishing grounds to Cardiff, have been calculated for the years 1922–1925, and from these means the figure is drawn.

It appears that from the 5th to the 9th full moons of the year there is a regular fluctuation in the landings, such that more fish is landed at full moon than at new moon.

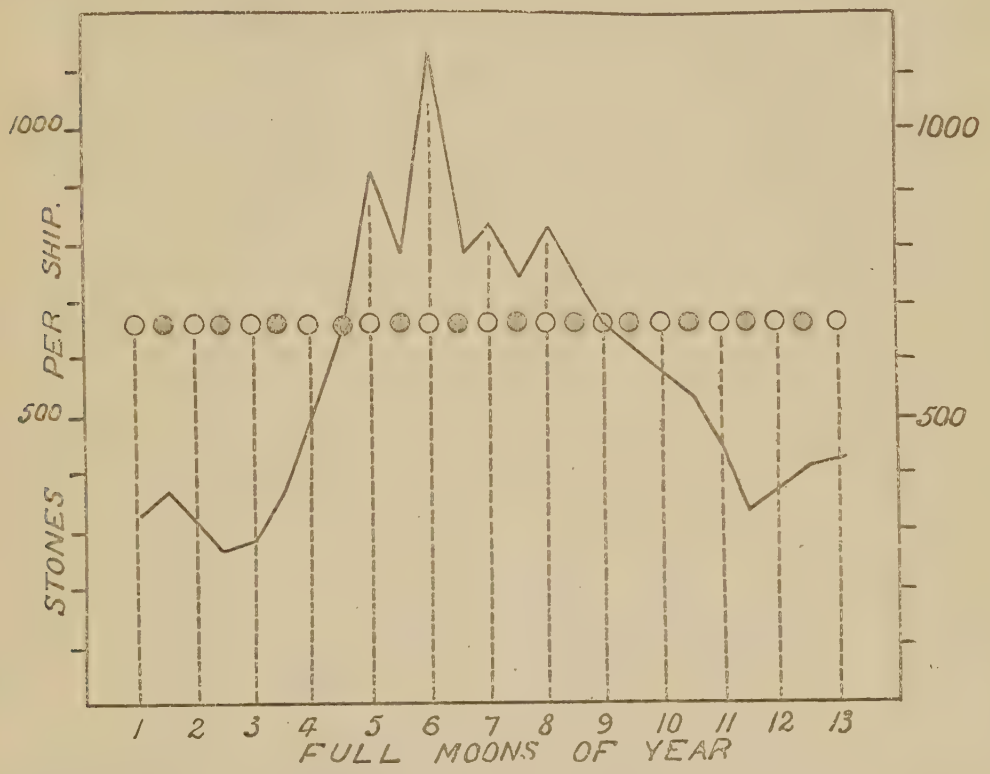


FIG. 7.—Mean landings of hake at Cardiff at new moon and full moon, for the period 1922 to 1925. Data in Appendix, Table X.

Moreover, if the frequencies of the " gluts " during these years are tabulated, it is seen that a remarkably large number of these have occurred at full moon, by which is meant, within a period of three days on either side of full moon. In drawing up Table III allowance has been made for a two-days' steam to Cardiff from the fishing grounds usually worked ; the crest of each glut has been assigned to the nearest phase of the moon, and in this way the table of frequencies has been drawn up.

But it will be clear that most fish will be landed by that ship which has had the greatest number of days' fishing during the glut period, so that the maximum catches will have occurred during her trip. An average voyage to the hake grounds lasts approximately 12 days, so that a truer idea of the rhythm, as it occurs on the hake grounds, will be given by fixing the crests of the glut periods six days earlier than the last day's fishing. This would point to the maximum occurring usually somewhere between the first quarter and full moon, and this is

consistent with what has actually happened in cases of which I have personal knowledge.

TABLE III.*

Showing the frequencies of "gluts," i.e., peaks in the weekly landings of hake at Cardiff, assigned to the nearest phase of the moon.

FREQUENCIES OF "GLUTS."

Phase of Moon	●	☽	○	☾
1922	2	3	5	5
1923	5	2	4	2
1924	5	1	5	2
1925	4	2	7	3
1926 to June 16	0	2	3	1
TOTALS	16	10	24	13

*Derived from columns 2 and 4 of Appendix Table IX—see text.

For example, during the spring and early summer of 1925 there was a clearly marked tendency for the fishing to improve during the first few days of each month, during which, also, there were fisheries, in shoal water, on spawning hake. Between the 5th and the 10th of May there were some big catches on the outer Fastnet grounds; between the 2nd and 6th of June there were big catches "below the Bull," in Lat. 52° 50′ N., in 120 fathoms, and also in 50 fathoms off the Old Head of Kinsale (spawning hake). Between about the 2nd and the 10th of July there was good fishing off the Hook, in 38 to 45 fathoms, also on spawning hake. Full moon in May was on the 8th, in June on the 6th, and in July on the 6th.

An approximately monthly periodicity is also shown in the well-known fishery off the Scillies, in 80 fathoms. The actual location of the fishery varies from year to year within an area in the vicinity of the Melville Knoll. In 1926 the hake were at Melville Knoll in the few days about the 26th of April, the 20th of May, and in the few days prior to June 2nd, for the fishery was over by that date. Full moon in April was on the 28th, and in May on the 27th. On April 26th there was also a sudden concentration of hake off the Fastnet, in 120 fathoms, and one ship took as high as 100 boxes in one haul. On June 19th, and the few days about that date, spawning hake were being fished off Galley Head, in 46 fathoms. First quarter in June was on the 18th, and full moon on the 25th.

It should be understood, however, that the most important evidence for a relation between the catch of hake and the moon's phases must rest on the trawlermen's own belief, so that the statistics quoted here are only to be regarded as an apparent confirmation. Moreover, having regard to the very crude and incomplete nature of the data used, and the many factors which might tend to mask the relationship, this note should serve simply to draw attention to a point which may be confirmed or rejected by any trawler owner interested, on the evidence of the landings of his own ships.

The explanation of the periodicity seems to lie in the spawning habits of the hake, which are very characteristic. Hake will suddenly appear in certain localities, usually in shoal water (about 60 fathoms) in great abundance, so that for a few days, or even, in extreme cases, for hours only, there will be an intensive fishery, when catches are very heavy. These concentrated fish are usually spawning, but concentrations also occur, apparently, among the ripe but not actually spawning fish, which are still in the deep water phase. These spawning concentrations, which are also usually associated with a continuous fishery, day and night, may occur as early as March, and as late as August and September, but in the south-western area they are most characteristic of the months from April to July.

These sudden concentrations, therefore, are probably in preparation for spawning, and for spawning itself, and ovulation and spawning apparently take place at approximately monthly intervals. In fact, it seems that at these monthly intervals, those hake among the ripening shoals, in deep water, which are ready for the final stage in the maturation of the crop of eggs, migrate inwards, usually into shoal water, as the final stage is passed, and spawn there. I have only found two or three female hake with ovaries in the " running " condition, among the many thousands I have examined from deep water. It is hoped that further light will be thrown on this question in my future paper on the sexual cycle and depth-migration in hake.

In the south-western area, the grounds visited in this way are small banks or knolls on the sea-bottom, such as lie off Galley Head, and at Melville Knoll off the Scillies : or else along the general slope, off the Fastnet, and along the Nymph Bank, off the Old Head of Kinsale, Minehead, and the Hook. There was also a spawning ground off the Smalls, apparently, but it has not been visited by the hake, in any notable quantity, since 1920.

These areas usually lie between the depths of 50 and 60 fathoms, though at Melville Knoll the spawning hake are taken in 80 fathoms, and I have seen them taken in abundance off the Hook in 38 fathoms : the spawning concentrations are therefore most typically a part of the shoal water phase of the fishery. This agrees with the account, given by Schmidt (1908) of the distribution of the young stages of hake, which were found chiefly between the 100 and 200 metre lines. He also says, however, that " to judge from our discoveries of quite small fry, it may spawn beyond the 1,000 metre line," and this agrees, again, with what is known of the habits of the hake, for sudden concentrations are known to take place occasionally beyond the 100 fathom line, such as occurred in April, 1926, off the Fastnet, two days before full moon.

In these concentrations, the majority of the hake are running males and females, i.e., actively spawning, and it seems that the females are the first to leave when they are spent, since, off the Hook, in July 1925, there were 80 per cent. males left when the fishery was over.

Trawlers will often fish for days in certain areas, in hope of being on the spot when the hake set in. A similar relation between the moon's phases and the abundance of trawled herrings and mackerel is said to exist.

There appear to be two possible causes of this periodicity, one external, due

to the tides, the other internal, a cycle in the reproductive activity of the fish. Pettersson (1912) describes an oscillatory movement of the salt undercurrent in the Skagerak and Cattegat, which has the tropic lunar period of 27 days, and he shows that the greatest herring catches are correlated with waves of salt water at the highest tides. But there are several factors which point to the conclusion that there is no such simple explanation in the case of the spring concentrations of the hake.

(*a*) The appearance of the hake is sudden ; there is no steady rise in landings such as one would expect if increasing catches were connected with the increasing height of the tides.

(*b*) As has been stated, the maximum catches tend to occur between first quarter and full moon, whereas the highest tides fall slightly after full moon.

(*c*) The lunar effect described by Pettersson is most intense in winter, and is weak in the summer months, when the hake's periodicity is best shown.

(*d*) In the Gullmarfjord there is a sharp difference between the fresh surface water and the salt water whose periodic oscillations carry into the fjord the herring shoals. On the fishing grounds the differences in salinity and temperature at different levels are usually very slight, so that the effect of an oscillation of the deeper water would be almost imperceptible.

But there is a case where the tidal effect, which reaches its maximum in the winter, may play an important part. Off Dubh Artach Light, in the Hebrides, hake may occasionally be struck in good quantity in winter, but the fishery lasts a few hours only. The fish is said to be there on rising tides, and it is certainly a phenomenon quite distinct from the spawning concentrations Dubh Artach lies between the sea-loch area and the Continental slope, in both of which hake is present throughout the winter, and the hake which form the fishery at Dubh Artach are regarded, probably rightly, as on a migration from the loch-area to the deep water grounds.

Pettersson (1912) suggests that the monthly oscillations of the deep water in the Gullmarfjord are generated by the increased quantity of more saline water which flows over the Wyville Thompson Ridge at the time of the moon's greatest tidal effect. Murray (1888) points out that the deep lochs are separated from the deeper sea-bottoms by sills, and also that in the winter months the warmer water is at the bottom, and colder water at the surface of these lochs. Mill (1893) explains how tidal movements may serve to warm the bottom layers in the deeper parts of the Firth of Clyde " by the tide drawing in over the great counter of the plateau slices of water from the mass " of the more oceanic water. It is possible that in the deep lochs there is an analogy with Pettersson's suggestion for the origin of the oscillations of salt water in the Gullmarfjord, and that rising tides cause more oceanic water to be drawn over the sill into the lochs, and introduce a factor which may cause a migration of hake from the lochs to the open sea.

It is difficult to explain the meaning of a monthly rhythm in the breeding habits of the hake. Such a rhythm occurs in animals as widely distributed as a hydroid (Elmhirst (1925)), polychaete worms, a sea-urchin, oysters, a fish, and man. In the present case, a tidal effect is disposed of, and moonlight can hardly have much effect on a fish living 60 fathoms below the surface of the sea; besides, the Thompsons (1919) state that the Grunion shows its monthly spawning run whether the moon is shining or hidden.

The oyster (Orton (1926)), a sea-urchin (Fox (1923)) and the fish, the Grunion (Thompson (1919)) spawn at or near, full moon ; the palolo worms usually at the first or last quarters. The authors are usually unable to suggest an explanation, but Orton indicates that " decrease of pressure, with increase of temperature at low water, are considered most likely factors " in the monthly spawning rhythm of oysters. Such an explanation is obviously inapplicable to the hake.

G. The Daily Change in the Hake Fishery.

The effect of a daily change in the abundance of hake on the sea bottom is shown by the record of any average voyage. Long experience has taught skippers that there is so little hake on the sea-bottom during the hours of darkness that it is rarely worth while to trawl at night, especially when the hours of darkness are long, as in winter.

Skippers say that the hake "take off" as soon as darkness falls, and that they return to the bottom shortly before daylight, hence it is usually the practice to shoot the trawl an hour or more before daylight, and to haul, for the last time, about two hours after sunset. Thus, in December, the trawl is usually shot at 5 a.m., and, if all is well, is finally hauled for the night at 8 p.m. In May and June shooting is usually at 4 a.m., and the last haul is at 10 p.m., and at this time it is the custom to make three hauls of six hours each during the working day,

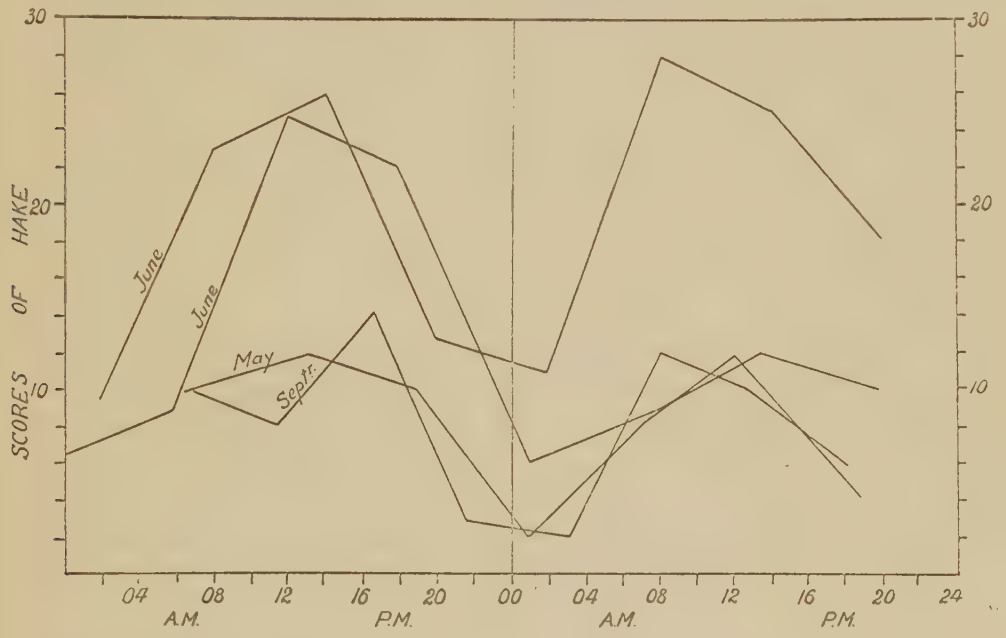


Fig. 8.—The catches of hake during two successive 24-hour periods in May, June and September. Data in Appendix, Table XI.

instead of two seven-hour hauls per day, as in winter. But it all depends on the quantity of fish being caught, the nature of the bottom, the depth, and risks of touching "coral" or getting full up with dogfish (in shoal water). On the northern hake grounds, where the bottom is very rough, only short hauls are made.

From April and May onwards some skippers make it a practice to tow during the short interval between the last night haul and the early morning shoot, so that trawling is continuous day and night. It was my good fortune in sailing with one of these skippers, Capt. Jones, of Milford, which has enabled me to obtain a continuous record of the quantity of fish caught per haul night and day, and so demonstrate graphically the effect of a daily variation in the abundance of hake on the sea-bottom.

There are three possible explanations of this. Firstly, the hake may become more able to avoid the trawl at night; secondly, the hake may leave the bottom together in a body; and, thirdly, the hake may spread out and scatter throughout the water-layers in pursuit of their prey, so that few will be found in the path of the trawl, at whatever level it may be fishing.

The graph in Figure 8 gives the course of the fishing during two successive days in May, June and September, respectively. Full figures are given in the Appendix, Table XI. It shows the catch of big and medium hake, in scores, for each haul throughout the two days, the catch being plotted for a point half-way through the haul.

It is seen that the maximum catches usually occur about mid-day, and that there is a sharp fall at night. This occurrence of the maximum catches when the sun has its maximum altitude for the day, and therefore its greatest power of penetration, has given rise to the belief that this daily cycle is directly associated with daylight; and this seems confirmed by the fact that during the summer months, when the sun's altitude is high, more hake is caught than during the winter, when its altitude is low, and also by the fact that during the winter months much less hake is taken at night in the trawl than during the nights in summer. None the less, I consider that light has no direct effect in this case.

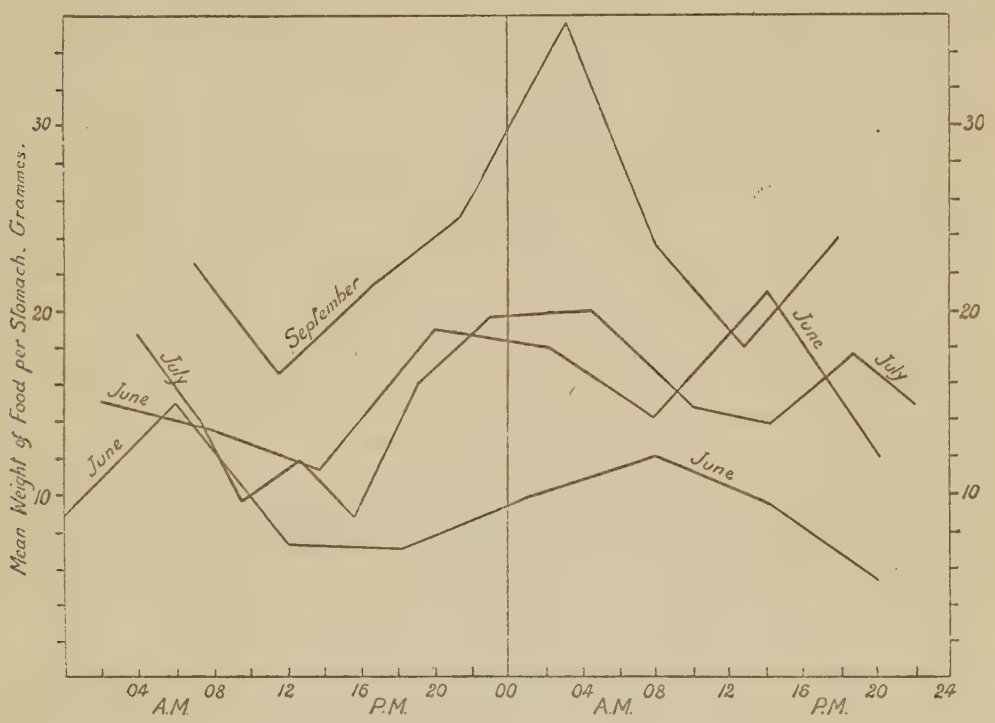


FIG. 9.—The fluctuations in the mean weight of the stomachs of hake during two successive 24-hour periods in June, July and September. Data in Appendix, Table XII.

As explained above, it is only during the spring and summer nights that those skippers who shoot at all at night, do so; it is for this reason that I am only able to furnish data to illustrate the daily cycle during the summer months. Occasionally, however, an accident may interfere with the ordinary course of the day's fishing during the winter, so that a skipper may shoot late in the afternoon and tow all night. This happened in November, 1925, and on this occasion three score of big and medium hake, and two baskets of small hake, were taken in a 10 hour haul, whereas, as Figure 8 indicates, in June as much as 11 score of hake may be taken in a 5-hour haul at night.

Now, Helland-Hensen, in "Murray and Hjort" (1912), showed that quite an appreciable amount of light penetrated to 1,000 metres (546 fathoms), so that at depths between 100 and 250 fathoms, where hake are taken during the greater

part of the year, there must be a distinct difference between night and day. An up and down movement, apparently induced by varying intensities of light, among other factors, is known among many delicate organisms which live in mid-water, so that they tend to move down into deeper water in strong light. This is well shown by the Euphausiid shrimps, which are of great importance, both directly and indirectly, to the hake. In an earlier paper I suggested that the hake might leave the bottom at night in pursuit of these shrimps, which form their ultimate food.

It is found that the hake does not feed by day. This is not only to be deduced from observations on the conditions of the stomach contents, which usually appear freshest in the morning hauls, and most "cooked" in the hauls later in the day, but actual weighing experiments indicate a fall in the mean weight of the stomach contents about mid-day. Conversely, the stomachs tend to be heaviest about midnight. This is illustrated in Figure 9, and fuller data are to be found in Table XII in the Appendix. Though, by day, the hake is taken in the trawl often with quantities of its prey, it does not feed.

Hardy (1924) notes that stomachs of herrings are usually definitely full or empty, and that "this would appear to indicate that the herring feeds hard and then rests, feeds and rests, the feeding times being closer together in May than in other months"; but he mentions no relation between this rhythmic feeding and vertical movement in herrings. Johansen's suggestion (1925) that the element of danger may be a factor in vertical migration cannot be accepted in the present case without modification, for the hake is itself a fish of prey, and one would imagine that it would be able more easily to hunt such fish as mackerel and blue whiting during the day than during the night. Hjort (1912), who gives a number of examples of deep sea fish and crustacea which show a vertical migration towards the surface at night, implies that they avoid light in order to obtain the fullest protection afforded by their dark colouration. It seems that no complete explanation is offered by considering the direct effect of light on hake in causing this rhythm in the fishery.

The feeding habits of the hake and its rhythmical appearance on the sea-floor, though so closely linked, may not be dependent on one another, but both may be due to a fundamental daily periodicity in the output of activity in the hake. The hake is a fish of nocturnal habits. It experiences alternating periods of activity and rest, and such a daily rhythm is almost universal among animals, while many cases are known among plants also. The hake hunts at night, during its period of activity, and as this period of activity gives way to the period of rest, which falls during the hours of daylight, the hake becomes inactive and no longer feeds. It then sinks, whether partially as a mechanical result of heavy feeding, or much more probably to seek the protection and support of the sea-floor during its period of inactivity.

On the other hand, Clark (1923) says: "They (hake) seem to feed on the bottom as much as in the upper layers of water. Trawling for hake may thus be more successful in day time as the pursuit of pelagic (i.e., mid-water) fishes is more likely to occur during night time, when the latter are known to come into the surface layers."

It is difficult to account for the presence of hake on the sea-bottom at all, for, according to my observations (see section I), they do not feed while they are there, nor do they feed, at any time, on bottom-living forms to an extent comparable with their chief class of food, which consists of mid-water fishes and squids. Moreover, there is something peculiar about the occurrence of hake on the sea-floor, for it is known to trawler skippers that if the gear is not fishing properly, so that the footrope and bridles come up unworn, very little hake is usually taken. The trawl must be squarely on the bottom, a fact which strongly suggests that the hake is not even floating near the bottom, but lying on the soil itself. This also appears to be the

opinion of le Danois (1921). The success of the new types of trawl, which have a headline buoyed up by glass globes, would seem to be in part due to the fact that fewer hake can leap clear of the mouth of the net, owing to the height at which the headline is believed to be carried above the sea bottom by the flotation of the globes, than could escape the older type of trawl.

There is a further note of great interest as to the occurrence of hake on the sea bottom. Hake, like other mid-water fishes, such as herrings and mackerel when these are taken in trawls, seem to lie on the bottom pointing head to tide, and in a narrow belt, for ships towing side by side for an equal length of time may make very different catches. A case in point occurred in March, 1926, on the fishing grounds " below the Bull," when three trawlers of the same fleet, of equal size and power, towed for an equal length of time on parallel courses, within half a mile of one another. On hauling, their catches differed by as much as 10, 12 and 20 boxes respectively. There are a good many other factors which might account for such a difference in reported catches, but the belief is widely held that hake lie very narrowly, so that the amount of fish caught will depend on the length of time during which the trawl is passing through the narrow belt of fish. Capt. Drennan compared this imagined distribution of hake on the sea-bed with the shoals of young fish which may occasionally be seen, in estuaries and harbours, stretching out like a long, thin ribbon, often only a foot wide, but hundreds of yards long.

It is well known that, if the trawl is towed across the tide, not much hake is caught, though this may be in part due to the difficulty in handling the ship and towing the trawl properly in a tideway.

It has been mentioned earlier that fishing for hake at night may be profitable during the late spring and summer, whereas in the winter there is very little to be caught in the trawl at night. This condition reaches its extreme in the spawning shoals, for, during the glut periods, as much hake may be taken at night as during the day, and a regular rhythm in the catches of hake may disappear.

At the same time, it was found that feeding was practically nil in those fish, which were spawning off the Hook Point in July, 1925. In spite of the shallowness of the water (38 fathoms), so that very few stomachs were everted by the change in pressure on hauling to the surface, only 3 per cent. of all stomachs examined contained any food. Yarrell (1836) quotes Couch to the effect that at its season for spawning the hake " keeps near the bottom, and loses the great voracity by which it is characterised at other times, so that multitudes are caught in the trawls and but few with a line." One would expect that the act of spawning would profoundly upset the normal rhythm in the life of the hake, so that the vertical movement from the bottom, and a rhythm in feeding, would disappear together. The question is further discussed in a later section.

This is probably the explanation of many of the known cases where hake has been taken as plentifully by night as by day. It is significant that the regions whence this has been recorded are usually only visited by trawlers at, or near, the spawning time of the hake in that region (Morocco in December and January, Biscay in March).

It is also said that in the Firth of Clyde, and in certain of the deep Scottish sea-lochs, such as Loch Linnhe, hake is to be taken at night in quantity. But very special hydrographical conditions are met with in these lochs, and Murray has shown (1888) that, overlying the more saline bottom layers where the hake lives with many other inhabitants of oceanic water, is a layer of less salt water where the food of the hake cannot live.

Besides these, however, there are undoubted cases where good catches of hake have been taken at night on the ordinary trawling grounds, and at a time when there could have been no spawning hake present. None the less, these are rare exceptions, and, generally speaking, hake trawlers do not fish during the hours of darkness, as they cannot then take enough fish to make it worth while.

As the period of activity in the hake returns, they spread and scatter throughout the water layers, without *necessarily* all leaving the bottom together. As mentioned in an earlier paragraph, a few hake may usually be taken in the trawl at night, but in agreement with the general rule that the quantity of hake taken depends upon their concentration in the path of the trawl, it is clear that vastly fewer hake will be taken by night than by day.

As I have stated, it is during this period of activity that the hake feeds. Nye (1887) gives an interesting note on the feeding of the American hake (*Merlucius bilinearis*). "They come in to feed from sunset to sunrise . . . during the daytime they are never seen alive near the shore, nor have I ever seen any at or near the surface in deep water."

Johansen (1925) states that the breeding migration of silver eels in the upper water layers takes place mainly or exclusively at night. He points out that the silver eels do not move upwards during the night in order to feed, but take up the pelagic habit in order to continue their breeding migration, which was broken off in the daytime. Johansen puts this migration down to a direct effect of light, but the case is so similar to the diurnal movements of hake that the explanation I have offered for the latter might well be applied to the silver eels also.

Attempts to fish with trawls at varying heights above the sea bottom have not been generally successful, though cases are known in which fairly good hauls have been made in circumstances which made it impossible for the trawl to have been fishing on the bottom. In any case it is safe to say that, had it been possible to catch hake is mid-water at night, the method would have been in general use long since; and while this failure may be due, in part, to technical difficulties involved in keeping trawls properly spread in mid-water, if the explanation given in this paper is correct, at no level would hake be found constantly in profitable quantities at night, in their scattered condition. Moreover, it is doubtful if a trawl could be towed at a sufficient speed to catch hake in their active state, though it is true that often, at night, two or three score of hake may be taken meshed in the wings and square of the ordinary trawl. Possibly the greater activity of the hake at night contributes to the low catches made by the trawl, in that many of the hake which are swimming near the bottom are able to avoid the net. It is very significant that all the successful methods of catching hake at night, which are about to be described, depend upon the hake actively seizing a hook or becoming entangled in trammels and seines, whereas trawling for hake by day depends upon the hake being swept passively into a slowly moving beam or otter trawl.

So far the effect of the daily cycle has been discussed from the point of view of trawling. It is interesting to note how it has affected other methods of catching hake.

Hake are rarely taken on long lines, which are usually set by day and hauled at night. Liner men whom I have known have only seen hake taken on long lines which have been left down after darkness set in. Smitt (1892) says that "in the Cattegat the hake is caught, partly with long lines, and partly with hand lines used for other fish. The bait consists of herring, or, still better, mackerel, and sometimes a bit of the fish is taken from the belly of hakes already caught." He does not say whether the hake are caught in this way by night or day.

Surface methods of catching hake are most successful at night. Fishing in mid-water with hook and line is mentioned by Day (1880), who gives the methods of catching hake, in his time, as "Line fishing by night in mid-water, and beam trawling during the day on the bottom." Pennant (1769) records that "it was no unusual thing for six men, with hooks and lines, to take 1,000 hake in one night" on the Nymphe Bank. Duhamel du Monceau (1772) gives us a note of rare interest on the methods of catching hake on the French coast. "The chief fishery for hake is carried on in Brittany at Audierne, Penmark, and the Isle des Seins. They fish during the night, three or four leagues out in the open sea, some with hooks and

others with trammels. While fishing, two men row continuously and relieve each other every two hours. If the boat were to remain motionless they would take almost nothing. They seek the fish down to a depth of 30 brasses (27 fathoms)." They used sardines, lancelets, other small fish and worms as bait.

Hake are taken plentifully among pilchards and herrings in seine nets (Yarrell, 1836, Ehrenbaum, 1910), and quantities of small hake are often found in herring and mackerel driftnets (Holt and Green 1891). A record is to hand of a drifter landing 28 kits of small hake, caught in drift-nets 16 feet below the surface, in April, 1926.

At first sight it seems remarkable that the hake, which has large and well-developed eyes, should do its hunting and feeding during the hours of darkness. But it is very probable that luminescence in the sea is much more general and constant than was formerly believed, and that the hake, when it hunts by sight, may follow the trail of light made by its prey. On dark nights, I have often looked down the stem of a steam-trawler while crossing the Nymphe Bank, especially just before the commencement of the Smalls' herring and mackerel seasons, and watched the fish darting away from the onward rush of the ship. Now singly, now in groups, they would streak away to left and right, each leaving a trail like a rocket. Sometimes one could see a fish shooting straight ahead for a second or two, as if unable to decide which way to turn, like a hen before a motor-car.

Light often has a powerful attraction for fish at night, and this is often turned to practical use; for example, by poachers who lure salmon by the light of torches. Johansen (1925) states that eels are repelled by light, and are frightened away from fish-weirs by lighting fires. But the Greek fishermen, according to Apostolides (1883), catch the Belone by luring the shoals to the shore with a fire kindled on one of the boats. Bean (1884) gives a translation of a Norwegian author who describes how, at many places in the Mediterranean, anchovies are caught by means of a torch, which attracts the shoals; these are then encircled by nets.

Herrings are " brought to a standstill " in the Altenfjord and other places in Norway by the use of light, and then scooped up with dip nets. The report of the Marine Biological Association for 1926 mentions the capture of adult pollack by hook and line within the area illuminated by a trawl deck light. I have suggested (1925) that a fish *Malacocephalus laevis* (Lowe), which is very abundant on the hake grounds, is enabled to escape pursuit by shooting out a brightly luminous fluid, which, remaining suspended in midwater, might attract the pursuer (possibly a hake) and so allow the fish to conceal its turn to escape. Osorio (1912) says that Portuguese fishermen use the secretion of the same fish for making luminous bait, by which they attract fish to their lines.

We can therefore imagine how a hake is able to hunt active prey at night, but it should be remembered that, in all probability, the pursuit is mainly a matter of scent, since fish are very short-sighted, and that the eyes are only used for the final snatch.

PART II.

FOOD AND FEEDING OF THE HAKE.

H. General Introduction. Remarks.

During the deep-water phase of the hake fishery, the vast majority of the fish taken contain no food, so that one is told that " the hake do not feed." Observations show that only about 12 per cent. of hake over 50 cms. in length contain any food in their stomachs, and in the deeper water the figure may be as low as 5 per cent. This introduces an obvious difficulty into any work on the food of the hake.

Two factors are involved in the apparent emptiness of stomachs. Firstly, there is the fact, which has been noted by other naturalists, that the hake when captured disgorges its food. Yarrell (1836), for example, says: " when hooked, the hake presently evacuates the contents of its stomach to facilitate escape, so that when hundreds are taken with a line in the midst of prey not one will have anything in its stomach. Couch (1864) says: " when caught at a considerable depth the fish ejects the contents of the stomach before it reaches the surface; there can be little doubt that terror is the exciting cause in every case, but it goes far to explain how it happens that many fishes, which, beyond doubt, are eager feeders, are generally found, when caught, to have their stomachs altogether empty." It is essentially a defensive measure, quite analogous to the emptying of the alimentary canal of very young transparent fish when alarmed.

Secondly, the sudden reduction in pressure, when the fish is hauled rapidly to the surface from deep water, causes an expansion of the air in the air bladder, which may burst into the general body cavity, and then, expanding still further, force the stomach, and in some cases the liver and the gut also, out of the mouth. The stomach is turned inside out by this process, so that it is impossible to tell whether it contained any food. This eversion of the stomachs of hake continues after the fish are shot down on deck, and the ejected food causes the catch to assume a peculiar smell, especially when the hake have been feeding chiefly on mackerel or horse-mackerel.

There are at least two factors controlling eversion of the hake stomachs, firstly, the depth of the haul, and, secondly, the physical condition of the fish.

A greater amount of eversion takes place in deeper than in shallow water. In the shallowest water in which I have seen hake caught in quantity (38 fathoms off the Saltees Islands) the percentage of hake with everted stomachs was not as high as 2 per cent. In 120 fathoms average counts showed that 55 per cent. of the hake were everted. It is for this reason unsafe to compare the actual quantity of food taken by the hake during the shoal-water phase of the fishing with that taken during the deep-water phase.

It is also noticeable that when the fish come up " strong alive " with the scales on, the colours natural and the skin still slimy, i.e., when the majority of the fish caught just prior to hauling, eversion is much less than when the hake appear " scoured," and have obviously been dragged along for some time in the cod-end. The physical condition of the fish is, therefore, a factor to be reckoned with in considering eversion. On one voyage, where the hake were usually everted to the extent of 80 per cent., two counts made on fresh hake, such as have

just been described, only showed 60 per cent. everted. While the hake is still alive, therefore, it may have the power of very rapid adjustment to sudden changes in pressure.

It is thus clearly possible that a large majority of these hake which, on being dissected, have empty stomachs, may have contained food, though all traces of what the food might have been have been lost. In a few cases fragments of food may be seen adhering to the teeth and beneath the tongue, when the stomach may appear normal, or, at most, slightly everted. The actual quantity of food found, therefore, gives no absolute indication of the true state of feeding in the hake.

The hake's habit of gorging has been frequently noted by other authors, whom it seems to have greatly impressed. Yarrell (1836) says that he has seen seventeen pilchards taken from the stomach of a hake of ordinary size. Couch (1864) says that when the hake is feeding on pilchards and herrings it is only when gorged to excess that its craving is satisfied. Smitt (1892) says that it eagerly follows the herring and pilchard shoals, and is said to destroy more fish than it can devour. Howell (1921) quotes Mr. H. E. Rees, of Swansea, who has taken 24 herrings from a hake weighing 14 lbs. (i.e. about 95 cms. long).

My observations show that gorging is the rule rather than the exception in hake. I have found 14 small specimens of the blue whiting (*Gadus poutassou*) in the stomach of one hake, and on another occasion a hake of 77 cms. in length, which weighed, without the viscera, 2,800 grams, had stomach contents weighing 1,100 grams. It is quite common to find that the stomach contents weigh as much as 25 per cent. of the weight of the whole fish.

This habit of gorging is often a source of serious loss to the industry, since a hake possessing such a heavy stomach will burst open at the slightest handling, or through the pressure of overlying fish, and thus become comparatively valueless. It has also been a source of serious difficulty in obtaining data to illustrate the daily feeding cycle in hake. For example, on one occasion an average weight for the stomach contents of a sample of hake was based on 36 stomachs; of these, 34 weighed 100 grams, the remaining two contained each a blue whiting, and weighed 1,008 grams. Again, during the same series of observations, 80 stomachs contained 960 grams of food, while the remaining four stomachs contained food weighing 200, 120, 220 and 130 grams each. Considering the difficulty introduced by this habit, as well as by the habit of expelling the stomach contents on capture, I am surprised that the weighing experiments have brought out so clearly a rhythmic change in the quantity of food in the stomachs of hake caught at different times of the day, as is shown in Figure 9 and Table XII.

This habit of gorging introduces a further possibility of error in work on the food of hake. Material is often found in the stomachs in a very fresh condition. All stages can be found usually in any haul, between a hake which has another hake's head in its mouth, to cases when the hake, or other fish, is found coiled up inside the stomach still fresh and uninjured.

The teeth of hake are specialised for seizing prey only, not for breaking it up, and its food is invariably swallowed whole. This habit was perfectly well understood by the naturalist, Aldrovandus, in 1638. The teeth are so constructed and hinged that, while they will bend inwards to allow of the entry of an object, they spring up when any attempt is made to withdraw it from the mouth; and, since there are teeth inside the mouth cavity, and in the gullet, the hake often cannot reject what it has once seized.

The hake, like the Monk (*Lophius*), has the habit of snatching up and swallowing, or partially swallowing, other creatures found in the cod-end at the same time. The most common of these adventitious stomach contents are hake of a smaller size, but macrurids, triglids, Spinax, and occasionally holothurians and echinoids may occur in this way, in the stomach contents of hake. This, also, probably

ounts for such records as those of Holt and Greene (1891) where echinoderms l brittle stars were found in the stomachs of a sample of hake.

In order to avoid, as far as possible, errors from this source, only forms have en considered which showed definite signs of digestion, and which, therefore, ving been in the stomach for some time, are most likely to be truly representative the food of the hake. This has caused a considerable loss of material, for many sh specimens have been rejected which may have been true food, while it has en been difficult to identify fish remains which were far gone in digestion. There several references, among earlier writers, to the quickness of digestion in the ke.

Fortunately, however, the hake feeds on quite a narrow range of forms, so that possibility of wrong identifications is not great, and it is fairly easy to dis-guish between these forms by such features as the scales, otoliths, teeth, skull l backbone. Moreover, as the prey lies coiled up in the stomach of the hake, inner side, which is not exposed to the churning action of the walls of the mach, may retain its natural appearance to a considerable extent, and so make ntification easy. The forms between which it was most difficult to distinguish re the mackerel and horse-mackerel; bib (*Gadus minutus*) and the *Gadiculus enteus*, small clupeoids and blue whiting; but I am confident that mistakes to this are few in comparison with the total.

I. The Food of Big and Medium Hake.

During a series of voyages to the hake grounds, observations were made on the d found in the stomachs of big and medium hake, by which are meant, in the sent case, all hake of more than 50 cms. in length. The precautions noted in the ceding section were observed in dealing with the stomach contents, and, wherever sible, the number of hake gutted during the observations has also been noted. food found on each voyage, with the locality and the number of hake gutted, iven in full in the Appendix, Table XIII.

The grand totals of all the voyages are given in the accompanying Table IV. range of selection shown by the hake is small. There are eight principal species, groups of species, and all the remaining forms are classed together as "other ns" in the bottom line of the table.

It is seen that the "blue whiting" (*Gadus Poutassou*) occurs most frequently the stomachs of hake, with the gadiculus second, and smaller hake third; kerel come fourth, cephalopod species (squids and fantails) fifth, clupeoids herring family) sixth, the smelts seventh, and the horse-mackerel eighth. numbers of each class found during the whole range of observations are given he second column of Table IV.

This list does not, of course, indicate the actual value of each group as food hake, because some of the forms in the list, such as mackerel and horse-kerel, are large, whereas others, such as the gadiculus and the smelts, are small. s, for example, while there are many more specimens of gadiculus than imens of horse-mackerel in the list, the fewer horse-mackerel actually represent r greater weight of food than the more abundant gadiculus. To allow for this or of size, the numbers of each item found by direct observation must be ghted in such a way that their relative value, bulk for bulk, as food, is more nfully represented.

A good estimate may be made in this way. A number of fresh specimens, say, lue whiting, are weighed, and their mean weight found. This weight, in round bers, may be considered a rough mean of all the large specimens of blue whiting n by the hake. When this mean weight is multiplied by the total number of e blue whiting found during the observations, the resulting figure represents

the total weight of large blue whiting then eaten by the hake. All the weighings are in grams.

To take the case of the blue whiting ; the second column in the table gives the number of specimens found, the third column gives the weighting coefficient, and the fourth column gives the total weight of blue whiting eaten by the hake during the period of observation, as found by multiplying the number of specimens in the second column by the coefficient. This has been done for all the remaining groups or species.

From the figures in the fourth column it is easy to calculate the percentage weight of each group or species, in the total weight of the food of the hake. These percentages are given in the fifth column.

TABLE IV.

The Food of the Hake, and the Relative importance of the various organisms eaten.

1	2	3	4	5
Kind of Organism.	Total No. found in all hake examined.	Mean weight of each food organism. (grams.)	Total weight of each kind of organism. (2) × (3).	Per cent. weight of each kind of organism in the total food (4) × 100 / 469011
Blue Whiting (*Gadus Poutassou*) large	934	180	168,120	35·8
„ „ „ „ small	221	17	3,757	·8
				36·6
Gadiculus argenteus	449	16	7,184	1·5
Mackerel (Scomber sp.) ... large	141	600	84,600	18·0
„ „ „ ... small	120	300	36,000	7·7
				25·7
Hake	278	350	97,300	20·8
Cephalopods	193	80	15,440	3·3
Clupeoids	171	100	17,100	3·7
Smelts (*Argentina silus* and *A. sphyraena.*)	67	30	2,010	0·4
Horse-mackerel (*Caranx trachurus*) ...	52	500	26,000	5·5
Other forms, chiefly Bib (*Gadus minutus*), Megrims, witches, pipers and gurnards	115	100	11,500	2·5
	2,741	——	469,011	100

The order of percentage weight shows wide variations from the order of abundance. Gadiculus, which is second on the list in order of abundance, contributes nearly least to the total weight of food, while horse-mackerel which contributes the smallest number of specimens, forms the fourth most important item by weight.

The Hake's Independence of the Sea-Bottom.

An important fact which emerges from a study of the food of the hake is that the hake draws little, or not at all, upon the bottom-fauna for its food, and that bottom-living animals and fishes contribute only a negligibly small proportion of the total food of hake. Even allowing for the arbitrary method of weighting used in the table, such forms contribute, at most, 2–3 per cent. With the exception of a few gar-fish (*Scombresox*), which were eaten in Galway Bay in September, 1925, the specimens grouped under the heading " other forms " all belonged to the bottom-fauna.

Of these, the bib (*Gadus minutus*) was easily the most abundant, forming at times, especially at the close of the shoal-water phase of the hake fishery, just before the last of the big hake return to deep water, quite an appreciably important item of food (see *Alida* voyage in Appendix). This was notably true in Donegal Bay in November, 1925, and off the Smalls in October 1924 (Hickling, 1925). At this season, food for the hake seems scarce, and feeding slight. In Donegal Bay, for instance, as the Appendix shows, there was only an average of 33 grams of food per fish, in spite of the shallowness of the water (45-50 fathoms) and consequent relative absence of eversion. This should be compared with the record of feeding in Galway Bay in September, 1925, when the food, which consisted chiefly of herrings and mackerel, amounted to no less than 256 grams per fish. These hake were newly spent, or partially spent.

The remaining forms under the heading " other forms " were the deep-water flat-fish megrims and witches, gurnards and pipers (*Trigla lyra*), and one or two invertebrates, such as the Norway lobster (*Nephrops*) and the ghost shrimp (*Pasiphaea*).

The fact that hake are independent of the bottom-fauna accounts for their indifference to the nature of the sea-bottom. During the greater part of the year, and especially during the deep-water fishery, the hake is taken on muddy ground, but this may be because the sea bottom on the steeper parts of the continental edge, especially in depths greater than 150 fathoms, consists largely of ooze; moreover the hake has a general tendency, at all times, to seek the deepest water, a tendency which causes it to collect in hollows such as the Peel Deep in the Irish Sea, in the deep trough east of Barra Head, in the muddy grounds off the Smalls, and " between the Banks." Silt naturally tends to collect in these hollows. But the well-known hake grounds " below the Bull " have a fine sandy bottom, and at times, especially in the spring months, hake are taken in quantity on rough and stony grounds such as lie off Loop Head, in Galway Bay, off the Bull Rock, off the Hook, &c. The deep water fishery S.W. of St. Kilda is worked on very rough ground.

There are frequent references in the literature to the effect of the nature of the sea-bottom on the quality of the hake. Hake taken on rough ground are said to be of better quality than those taken on muddy bottoms. An expert fish buyer is said to be able to distinguish hake taken in Galway Bay, which consists largely of rough ground, from hake taken in deeper water. Apart from the fact that hake, when in the shoal water prior to, and during, spawning, are near their best condition, I would suggest that, as far as trawled hake are concerned, the considerable friction of the stream of mud or sand particles passing through the " cod end " must tend to " scour " the fish and injure the firmness of the skin. This effect would be slight or absent on rough or gravelly bottoms.

J. Notes on the Species Forming the Food of the Hake.

Clupeoids.—Under this head have been grouped together the herring, the sprat, and possibly also the shad (*Clupea alosa*). I may say that herrings, chiefly small specimens, formed the vast majority of the fish under this heading.

Mackerel.—The mackerel which occurred in the stomach-contents of hake taken in the deep water were mainly very large specimens, but it was necessary to create a special class of " small mackerel " to include the forms found in the stomachs of hake taken in Donegal and Galway Bays. This feeding of hake on young mackerel in the Irish bays is well-known and is referred to in the literature.

The clupeoids, the mackerel and the horse-mackerel (*Caranx trachurus*) are all well-defined pelagic fishes.

The pelagic nature of the Squids is also well known. Here also bottom living forms such as the Octopod (*Moschites cirrhosa*) did not occur in the stomach-contents of hake, though they were often taken in the trawl, and occasionally in the stomachs of cod, in the shoal water. The most abundant of the squids on which hake feed seem to be the fantails *Todaropsis eblanae* and *Ommatostrephes sagittatus*, but *Stenoteuthis* has also been found, and off St. Kilda in January, 1926, hake were feeding quite heavily on the squid *Loligo*. Hjort (1912) has observed these squids swimming near the surface in the open sea off the Norwegian coast banks, and notes that they are often found in the stomachs of cod. Farran (1923) says that occasionally large squids of a reddish colour (*Ommatostrephes sagittatus*) may be seen swimming near the surface on calm nights off the Irish coast.

Of the Smelts (*Argentina*) the smaller species *Argentina sphyraena* was the more plentiful in these hake stomachs. *A. Sphyraena* was wrongly described as *Osmerus eperlanus* in my earlier paper (1925).

Day (1880), Smitt (1895), and Holt (1897) all indicate that the Argentines are deep-sea forms, probably bottom-haunting, and records of the food of these fish made by Scott (1901) and Edwards (1881) point to a bottom-feeding habit. But specimens recently brought to Plymouth from Biscay were found to contain chiefly the Pteropod *Clio*, and I have always found that the smelts taken along the edge of the deep water feed pelagically. I have, therefore, felt justified in considering the Argentines as pelagic for the present purpose. Schmidt (1908) definitely states that *Argentina silus* is a pelagic fish.

According to my observations *Argentina sphyraena* penetrates into the shallowest and least oceanic waters fished for hake, and judging from its relative abundance in the trawl *Argentina silus* seems to occur most abundantly during the spring months, the maximum numbers more or less coinciding with the appearance of the salp-shoals. It is then also that Argentines reach their greatest relative value as food for the hake (see Appendix, Table XIII). I have found ripe females of *Argentina silus* trawled from 250 fathoms in Latitude 52° 40′ N. in May, 1925.

Gadiculus argenteus has been found by Holt (1895) off the South-west coast of Ireland, the adults at depths from 144 to 220 fathoms, the young from 52–80 fathoms. My observations agree with these. Very small specimens are found in the stomachs of small hake in the shallow water near the continental edge, and the large specimens are found abundantly in the hauls from depths between 120 and 250 fathoms. Most of these specimens are found, spot-fresh, in the mouths and stomachs of hake, black-jacks (*Gadus virens*) and the lings, and have, no doubt, been snatched up while the fish were all together in the cod-end of the trawl.

Holt concludes that Gadiculus is a fish that lives " on the borders of the abyss, never rising into quite shallow water, and never, apparently, penetrating into very great depths." Schmidt (1908) implies that it is a bottom-living fish. But, like the smelts, the gadiculus is apparently an exclusively pelagic feeder, and I consider that it should be regarded as a midwater fish.

I have found very small silvery specimens of *Gadiculus argenteus* in the stomachs of small hake taken in 160 fathoms off St. Kilda. Schmidt found the fry most abundantly " on both sides of the Rockall Channel." I have found ripe roes in these fish late in May off the south-west coast of Ireland.

But far more important than the foregoing forms is the Blue Whiting. Table IV shows that it forms 36·6 per cent. by weight of the total food of big and medium hake examined.

Schmidt (1908) says of the blue whiting: "It is in high degree a pelagic fish," and says that it may be present in such numbers over the deep water that he was able to take adult specimens in the slow-moving young fish trawl. Holt (1895) records that a large shoal of young blue whiting was observed near the surface over 175 fathoms, 34 miles off Achill Head. "The fish captured . . . presented no sign, by distention of the air-bladder or otherwise, of having been driven up from any considerable depth." Howard Dunn (in Day, 1880) describes how in 1861, 1871 and 1881, young blue whiting came in swarms to the coast of Cornwall, but it is distinctly oceanic in its distribution, and I have not seen it further from the continental edge than off Galley Head, on the south-west coast of Ireland. Like the herring and mackerel, the blue whiting may be abundant in the stomachs of fish, and yet be found in the trawl in very scanty numbers. On the Porcupine Bank, in October, 1926, hake were feeding heavily on blue whiting, yet even with the help of the crew it was often impossible to find enough specimens to enable a weighing and classification of the stomach contents to be made. I have not noticed any definite evidence for a regular vertical migration in blue whiting, and its appearance in the trawl is apparently quite fortuitous. At times, such as occurred in July, 1926, in Latitude 52° 50′ N., in 130 fathoms, three or four hundred specimens may be taken in one haul, so that the fish becomes a serious nuisance.

The spawning time of blue whiting, according to Schmidt (1908), is in late winter and early spring. During the summer months adult specimens have roes and testes too small to notice in gutting, but in October these organs had grown markedly in size, and were fairly conspicuous, though still undeveloped. On the westward grounds (Lat. 49° 50′ N. and southward) I found the ovaries of the blue whiting ripe for spawning in February, and a month later on the more northerly Irish grounds (below the Bull) in Latitude 53° 10′ N. A few ripe specimens occurred as late as April in the last-named area. The depth at which ripe specimens were taken was always great—between 180 and 300 fathoms (the deepest water worked)—so that, remembering that the fish is pelagic, it would be present in a ripe condition over deep water. Schmidt gives its spawning place as in the neighbourhood of the 1,000-metre line, and says that spawning probably takes place in midwater, since the greater number of very small fish occur near the surface.

K. Seasonal Changes in the Nature of the Hake's Food.

A simple statement of the total food of the hake means little unless seasonal changes in the feeding of the fish are taken into account. In the course of the annual migrations described in the section on the annual cycle, section C, the hake is carried into shallower and less oceanic waters, and then feeds on a different class of fish from that which forms its food in the deep water. Hence the percentage composition of the total food of the hake will vary accordingly as the greater part of the observations have been made during the shoal-water or the deep-water phase of the fishery. It so happens that the great majority of the voyages, during which this work was done, were to the deep water, hence the list given in the table may contain a deceptively large proportion of more oceanic fish.

To give a truer idea of changes in the nature of the food of the hake with the changing phases of its annual cycle, Figure 10 is given, which shows, graphically, the percentage by weight of each of the five chief food-fish of the hake at the rough mean depth of the trip which supplied the data. This method neglects the seasonal movements of the food-fishes themselves, and this accounts for the very irregular curves which are obtained. For example, in April, 1926, in 125 fathoms, when the hake fishery was still moving into shallower water, the blue whiting, which was

apparently moving inwards at the same time, formed by far the most important item of food, while mackerel were few. But in July, 1926, in the same locality, when the hake fishery was beginning to move back into deeper water, big mackerel appeared in numbers on the hake grounds, so that the percentage of mackerel rose and the percentage of blue whiting fell considerably. It is very likely that the low percentage of blue whiting on this occasion was partly due to an outward movement, away from the hake grounds, of this fish.

The high percentage which appears at 175 fathoms is due to a trip to the Porcupine Bank (Long. 14° 10′ W.) in October, 1926. Coastal forms are totally absent from the stomach contents of hake at this time, and this, no doubt, accounts for the very high percentage of blue whiting, which is a typically oceanic pelagic fish.

The full data, on which Figure 10 is constructed, will be found in the Appendix, Table XIII.

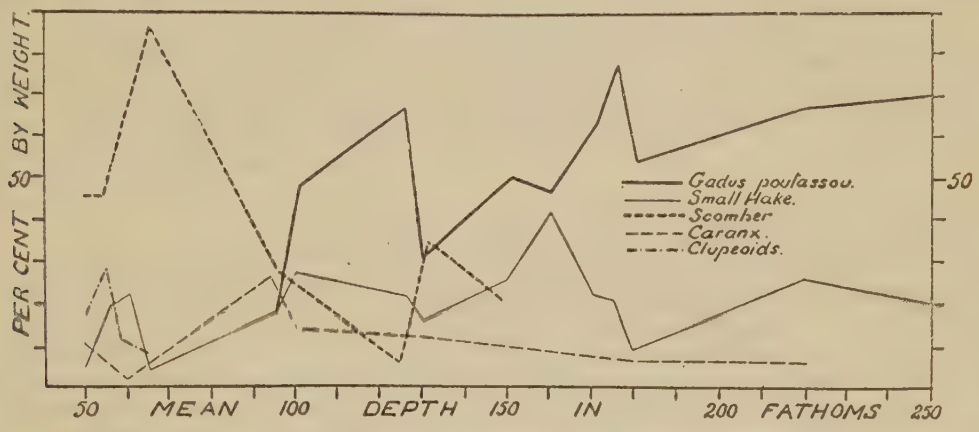


Fig. 10.—The change in the nature of the hake's food during the seasonal depth-migration. Data in Appendix, Table XIII.

The general trend of the curves is to be seen clearly enough. In the shoal water mackerel predominates, with herring, and, to a lesser extent, small hake and horse-mackerel. This bears out the older accounts of the food of the hake, such as those of Pennant (1769), Donovan (1808), Yarrell (1836), Thompson (1856), Couch (1864), Day (1880), Smitt (1892), Ehrenbaum (1910) and le Danois (1921), in all of which the hake is described as feeding on mackerel and clupeoids. Day, for example, describes how it "accompanies shoals of herrings, mackerel, pilchards, sprats, and anchovies, on which it feeds." Smitt says that during the greater part of the year it lives alone or follows the herring and mackerel shoals in companies. Le Danois (1921) says that hake feed chiefly on herring and mackerel, and failing those, feed on each other. During the Smalls herring and mackerel seasons, from July and August until October, there is often enough hake on the outskirts of the herring fleet to pay a small trawler well, but they are chiefly small and medium hake at the present time. They feed heavily on small clupeoids (see Appendix, Table XIII, *Trawler Prince*, VI, &c.). When in the shoal water, therefore, hake remain faithful to their habit of pelagic feeding, except occasionally at the very end of the shoal-water phase, when food becomes scarce. It is not possible to speculate as to what extent this scarcity of food contributes to the return of hake to the deep water.

The American hake, *M. bilinearis*, according to Goode (1884) "comes to the surface to prey on the schools of herring and other small fish, and is frequently caught in the mackerel and blue fish nets."

When these earlier authors wrote, the deep-water hake fishery was not yet exploited. Referring again to Figure 10, it is seen that herrings no longer appear in the

stomachs of hake taken deeper than 70 fathoms, and that mackerel disappears at about 150 fathoms. On the other hand, blue whiting appears, first, in the stomachs of hake caught at about 95 fathoms, and it is at this depth also that the horse-mackerel reaches its greatest relative importance. From the point of view of feeding, therefore, the line of division between the shoal-water phase and the deep-water phase lies between 90 and 100 fathoms, and I have a very interesting note on the food of hake caught off the Bull in 95 fathoms, on May 23, 1925. Both blue whiting and mackerel occurred together abundantly in the trawl, but the hake were distinctly selecting mackerel in preference to blue whiting. In one sample of stomachs there were eleven mackerel and three small hake, but only one blue whiting.

As the water fished for hake becomes deeper the blue whiting becomes relatively more important, until in 250 fathoms it forms 70 per cent. of the total weight of food taken by the hake. Small hake seem to reach their greatest relative importance as food for hake at intermediate depths of 100 to 170 fathoms.

The feeding of hake may be summarized thus :—It is entirely independent of the sea-bottom ; the hake feeds almost exclusively on a small group of mid-water fishes and squids. This holds good both for the deep and shallow water phases of the fishery. The blue whiting (*Gadus poutassou*) is by far the most important food of the hake in deep water.

L. Seasonal changes in the Intensity of Feeding.

In section H the question of the eversion of the stomach in hake was discussed, and it was pointed out that the degree of eversion depends partly on the depth from which hake are taken. It is greater in hake trawled from deep water than in hake trawled from shallow water, hence, if feeding does not vary in intensity throughout the year, one would expect that less food would be found in the stomachs of a sample of hake from deeper water than would be found in a sample from shallow water. Yet there is evidence, which will be discussed in this section, to believe that in spite of the favouring factor of less eversion, the mean weight of food per fish becomes progressively less as the hake fishery moves into shallower water in the annual cycle of changes described in the first section of this paper.

In order to compare the mean weight of food found in big and medium hake in successive voyages the following procedure has been adopted. In the Appendix are given the numbers of each kind of fish eaten by the hake during each voyage. These numbers have been weighted in the manner described in Section H (where the total food of hake was discussed), and in this way the total weight of food taken by hake during each voyage is obtained. This weight, divided by the number of hake gutted, gives the weight of food per fish.

The weight of food per fish in successive voyages is shown in the graph (Figure 11). The whole series of observations on which this graph is based were made for one natural fishing area, namely, the grounds " below the Bull," between Latitudes 52° 10′ N. and 53° 30′ N., and the Porcupine Bank (Lat. 53° 10′ N., Long. 14° 30′ W.), which was visited once, in October, 1926. My work has led me to believe that the hake found on the Porcupine belong to the same stock as those caught during the greater part of the year " below the Bull."

In the same graph are also shown the depths of the voyages which supplied the data, and the mean weight of the roe in big (female) hake at the time of the observation. The data are given in the Appendix, Table XIV.

The deep water phase of the fishery only is included in the graph, and no attempt is made to compare the rate of feeding in the shoal-water phase with that in the deep water.

The curves deduced from these data point to the following conclusions as to the cycle of changes in the intensity of feeding in big and medium hake. In September, a shoal of hake whose roes were, on an average, empty, showed a very high level

of feeding. These hake were taken in comparatively deep water (170 fathoms). In December the mean weight of the roe was even less, showing that the great majority of the hake were spent, and the fishery had moved into very deep water (220 fathoms); the intensity of feeding had fallen considerably. But this heavy fall is certainly due, in part, to the great increase in depth, and consequent great eversion.

In March, when the roes were well on the way to recovery and the fishery had moved into less deep water (160 fathoms), the level of feeding was even lower than it was in December, in 220 fathoms, indicating a very real falling off in the intensity of feeding. This falling off is maintained in May, though the fishery is still moving into shallower water, until, in early June, it is very low (33 grams per fish) in spite of the shallowness of the water in which these fish were caught (100 fathoms).

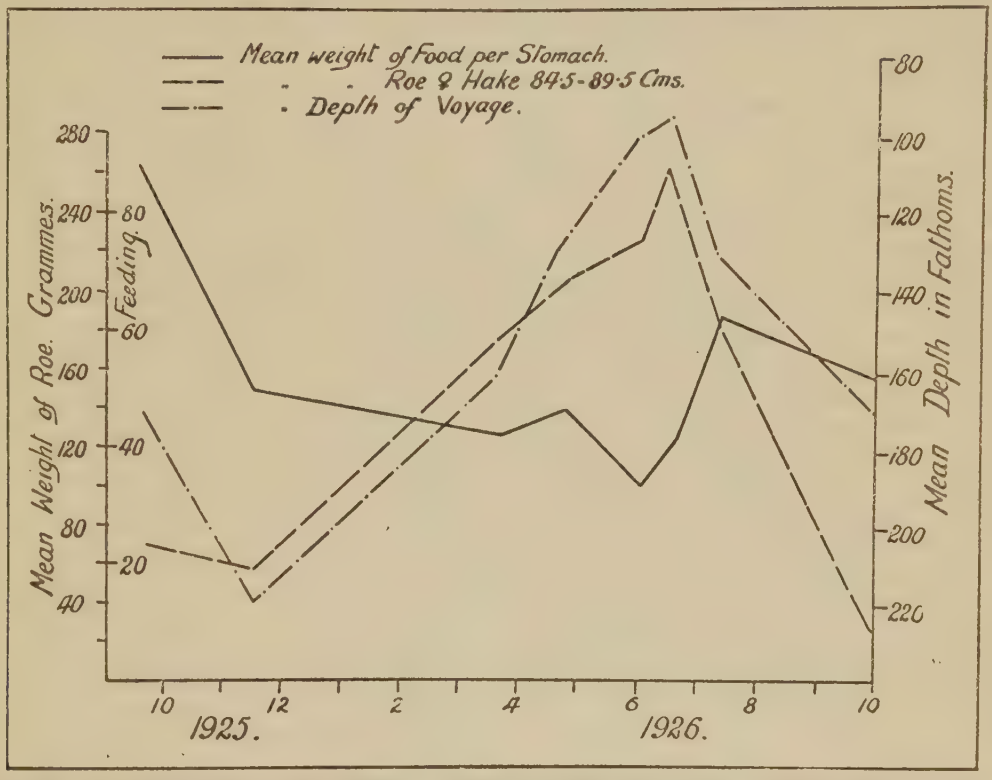


FIG. 11.—The variation in intensity of feeding and its relation to the sexual cycle in hake. The mean weight of roes refers to female hake of 84·5—89·5 cms. Data in Appendix, Table XIV. Points are plotted according to approximate mid-point of voyage.

After this point, there is a striking change. In late June feeding showed a decided recovery, and at the same time the first spent fish appeared. They were too few in number to affect the mean weight of the roes, which continued to rise, owing to the further ripening of the majority of the fish; in the same way, the fishery continued, on the whole, to move into shallower water (95 fathoms).

In July, this process is carried much further. Spent fish are more numerous, comprising, in the deepest hauls, as much as 20 per cent. of the female fish, and their presence is responsible for the drop in the mean weight of the roe. This drop is accompanied by the commencement of a movement of the fishery back into deeper water, and also by a very sharp recovery in the intensity of feeding, which is once more high.

Finally, in October, 1926, the rate of feeding was still fairly high, though the fish were once again being caught in deep water.

Summing up, one may say that the intensity of feeding in hake is related to the condition of the fish, and that, as the breeding time approaches, with the accompanying great development of the roes and milts, feeding falls away. On the other hand, when spent fish commence to influence the hake shoals, feeding at once becomes vigorous, and it is clear that in mature hake feeding is most intensive after spawning.

The actual spawning of the hake takes place chiefly in shallow water, and therefore the process described above cannot be followed to its climax, but in the section on the daily cycle it was indicated that at spawning it is very rare to find a hake with any food in its stomach, and this in spite of the fact that the fish are being caught in comparatively shallow water.

As soon as spawning is accomplished in the shallow water the hake feeds very voraciously, chiefly on herring and mackerel. This was the case, for example, in Galway Bay in September, 1925, where no less than 259 grams of food per fish was found in the stomachs ; and though one must take into account the shallowness of the water in which these hake were caught (60 fathoms), it is plain that feeding must have been very intensive. They continue to feed heavily on their return to deep water, though now chiefly on blue whiting, until, in the course of the changes noted above, feeding slackens with the ripening of the roes.

It is noteworthy that in Donegal Bay, in November, 1925, a shoal of hake, which were spent to about the same extent as the Galway Bay hake just referred to, contained on an average only 35 grams of food per fish, as against the 259 grams per fish in Galway, though in Donegal the hake were being taken in even shallower water (50 fathoms). It has already been noted that these hake also were feeding to a considerable extent on the sea-bottom fauna. The continued presence of spent hake in shallow water where food was scarce points to the conclusion that the return of mature hake to deep water is not associated with the search for food.

But the intensity of feeding is probably to be regarded as an indication of the state of activity of the fish. When the roe is spent the hake is in its most active condition. The remarkable rapidity with which hake disappear from a spawning ground is probably a manifestation of this sudden return to activity and the re-awakening of hunger ; in a similar way, the fact that just before and during spawning hake may be taken in almost as great a quantity by night as by day, in trawls, points to a greatly diminished activity associated with the absence of feeding and with the very heavy roes. The fact that hake are taken on the slopes of the Porcupine Bank (Long. 14° 10′ W.) at the time when their roes are lightest and feeding high may be taken as a further indication of activity at this time. The period of maximum activity seems to coincide with the period of widest distribution.

The distended roes may well have a mechanical effect in reducing the amount of feeding and the activity of the fish, but by analogy with the salmon, the eel and the herring, we must consider that there is a biological factor also present to inhibit the feeding function. Jordan (1925) says of the Quinnat Salmon : " In the rivers they do not feed ; and when they reach the spawning grounds their stomachs, pyloric caeca and all, are said to be no larger than one's finger." Petersen (1896) says that silver eels (which are approaching the breeding period) are rarely caught on baited hooks, though yellow eels (which are immature) form the great majority of the catch. " This must be explained by the much greater voracity of the yellow eels, a fact which is fully borne out when we examine the contents of the stomachs of eels which have been caught in other ways ; the silver eels generally contain nothing, though it may happen, particularly when the eel has perhaps not quite finished the change of its dress. When it is migrating in its full characteristic dress I never saw any food in its stomach." Six weighings of the digestive organs of yellow (immature) eels gave a mean weight of 25 grams, whereas five weighings of the digestive organs of silver (maturing) eels gave a mean

weight of 1·6 grams only. I am able to suggest that the blue whiting also feeds much less as its spawning time approaches.

Todd (1907) shows that, to judge by the percentage of empty stomachs, the plaice, dab, flounder and sole feed very much less in winter than in summer. These are winter-spawning fish.

Hardy (1924) is able to go very much further in this direction in his paper on the food and feeding of herrings on the East Coast of England. He shows that " there is a rapid increase in the taking of food in spring, reaching a maximum at the end of May, followed by a gradual decrease throughout the summer to a period October to December, when feeding is almost entirely suspended," and further, " that the annual cycle and the formation of winter rings on the scales would appear to be due to the annual cycle of feeding." It is a pity that no data were given to show the simultaneous changes in the mean weights of the sexual organs, but presumably the time when feeding is almost suspended coincides with the spawning period of herring on the East Coast.

The effect of the feeding cycle of the hake on its growth cannot be discussed here, but one may point out that, in the case of herring, the period of minimum feeding coincides with the winter time of low temperature, so that both physiological and physical factors combine to retard growth at about the same period; but in the hake, which is a summer-spawning fish, the time of minimum feeding occurs in the late spring and early summer, when the temperature of the water is rising. One would expect, therefore, that the checks due respectively to a lower winter temperature of the environment, and to an internal factor associated with the ripening of the roes, since they do not coincide, would each produce a separate check, and a slight one, compared with the strong check which the two factors combine to produce in the spring herring. Birtwistle and Lewis (1924) say of the hake scale: " We have the utmost difficulty in reading scales. This is due partly to the extreme faintness of the rings in some cases, but more particularly to what we consider a system of double ringing." This interesting problem must be left at the present stage, with this brief suggestion.

M. The Food of Hake's Food.

Small hake.—It must be remembered that the work on which this paper is based was done on fishing vessels which were mainly out to catch hake; and as big hake will fetch at least four times the price of small hake, as a general thing, the skippers of these ships sought the bigger sizes of hake only, and followed these in their movements as far as possible. Notes on small hake apply chiefly to fish taken along with the big hake, so that only a general account of the feeding of small hake can be given. It is certain that, while small hake have an annual migration similar to that of big hake, they spend much more of their time in shallower water, and may make movements which bear little relation to those of mature fish. The justification for giving a more exhaustive account of the feeding of big and medium hake lies, obviously, in their much greater importance to the industry.

Small hake, like big hake, are typically predatory, and are almost exclusively mid-water feeders. On the whole their food is much the same as big hake's, except that, with their smaller size, a smaller class of fish is eaten, so that, for instance, the gadiculus is far more important to small hake than to big hake. As the size of the hake dealt with becomes smaller, we naturally find them turning more and more to small invertebrate forms for food; but this tendency varies very much at different times of the year, and also with the relative abundance of various kinds of food. Hake as small as 21 cms. may be feeding on fish, and a case is quoted where a hake of this size, weighing 50 gms., contained a (small) blue whiting, weighing 15 grams. On the other hand, when the Euphausiid shrimp *Meganycti-*

phanes norvegica is present in great abundance, hake up to 64 cms. in length have been seen feeding heavily on it.

This recalls the case of the cod, which, as Todd (1907) shows, feeds wholly upon Crustacea when small, but turns more and more to fish food as it grows larger.

During the winter and early spring, when big hake are in their deep-water phase, small hake are found feeding directly on " kril " (Meganyctiphanes), but principally on small blue whiting and the gadiculus, with an occasional small squid. They also feed to a lesser extent on small Argentines, and are sometimes found with deep sea bathypelagic fish, especially scopelids. Four specimens of *Scopelus Mulleri* (?) were found in the stomach of a hake caught on the outer slope of the Porcupine Bank (Lat. 53° 10′ N., Long. 14° 15′ W.) in October, 1926, but they occur most frequently in hake caught in the very deep water on the westward grounds Lat. 49° 50′ N. and southwards), which are worked in late winter and early spring.

The only bottom-living forms found in the stomachs of small hake are occasional Pandalus, Pasiphaea, *Sergestes arcticus*, small Nephrops, and *Cirolana borealis*, but bottom-living species are rarely met with in the stomach contents, and must form, as in the case of big hake, only a small percentage of the total food taken in deep water.

In spring kril appears abundantly on the deep water hake grounds, and in areas where kril seems concentrated, small hake will be found feeding heavily, and at times exclusively, on it. There is no doubt that small hake select kril, when this is present in sufficient quantity. At other times small hake continue to feed chiefly on small blue whiting and gadiculus.

In early summer when the hake fishery has moved into the neighbourhood of the 100-fathom line, kril appears less and less in the stomachs of small hake. At this time they feed chiefly on a small year-group of blue whiting, which appears in vast numbers at this time, and is the food of black-jacks (*Gadus virens*), large hake, and large blue whiting. I have found specimens of a still smaller year-group of blue whiting in the stomachs of small hake taken in June, 1926, in latitude 52° 25′ N., longitude 11° 36′ W., in 98 fathoms. An entire specimen was examined. It was 38 millimetres long, and certainly belonged to the current year's brood. Thus from its very birth, the blue whiting seems destined to serve as food for hake.

During the shoal-water phase of the hake fishery, small hake feed heavily on small mackerel (Donegal Bay, Galway Bay, Fastnet), small herrings (all along the south coast of Ireland, and off the Smalls), small Cephalopods (especially a shoal of small specimens of *Loligo*, off the Saltees, in March and July, but otherwise chiefly *Rossia* and *Sepiola*) and Euphausiid shrimps. However, as remarked earlier, smaller hake tend to feed more upon small crustacea and less upon fish. Thus, on one occasion, small hake of an average length of 36 cms. contained kril in 11 per cent. of stomachs (including in the percentage empty and everted stomachs), where hake of 21 cms. contained kril in 30 per cent. of stomachs. Also individual hake have a strange habit of selecting and feeding entirely on kril. Thus, I have found that, in a sample of stomachs full of small herrings, one or two would contain pure kril. I have found remarkable cases of selective feeding even among flat fish, such as the megrim. A megrim will be found occasionally stuffed out with pure kril where all other specimens will contain only a chance specimen among their other food of small fish, &c. Selection in feeding is difficult to understand, but, as Graham (1924) points out, " the less abundant food is, the more kinds will be taken," and when fish are found selecting a particular species, one may infer that this species is generally abundant. The importance of this becomes apparent in a later section.

The feeding of small hake on Meganyctiphanes, which it selected in preference to Nyctiphanes and Thysanoessa, was described in my 1925 paper. Off the Fastnet in May, 1925, small hake were feeding chiefly on Nyctiphanes and

Thysanoessa, the number of Euphausiids found in a sample of stomachs being as follows :—

Nyctiphanes, 440. *Meganyctiphanes*, 27. *Thysanoessa*, 84.

The few hake which are left in the shoal water between December and March (see section O and figure 12) seem to feed very little, so that, in spite of the fact that eversion is not general owing to the slight depth, food is rarely found in their stomachs.

They are then feeding, however, on the bottom fauna, *Crangon allmanni*, Pandalus, Pasiphaea, and the small fishes, Crystallogobius, Callionymus, and Bib (*Gadus minutus*) are its chief food, and this special case, with the case already quoted where, in Donegal Bay in November, bottom-living forms comprised 25 per cent. of the total constituents of the stomachs of hake at a time of scanty feeding, are the only occasions where the sea-bottom has been drawn upon to any extent to supply the hake's food. It must be made clear, however, that very few hake are found in

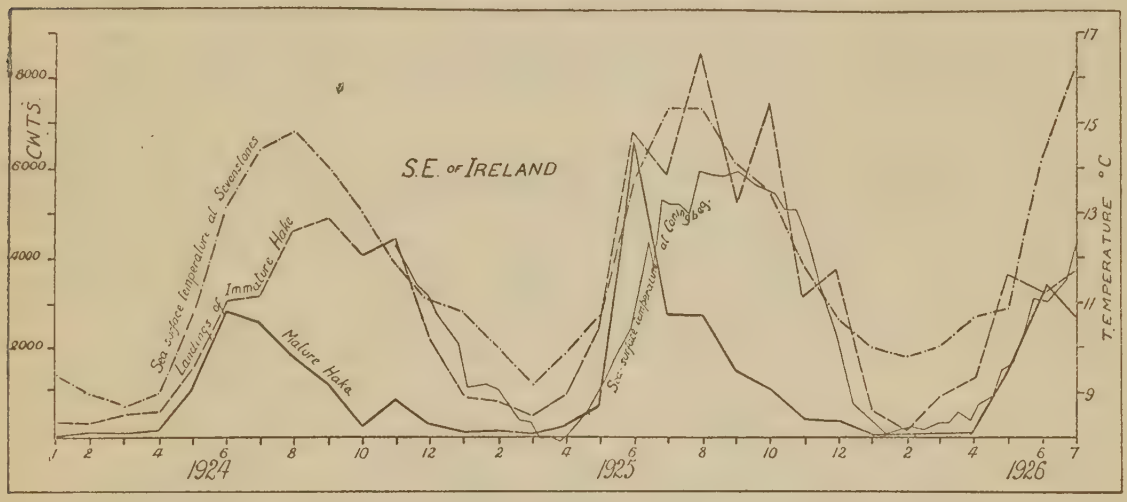


FIG. 12.—The quantities of big (mature) hake, compared with the quantities of small (immature) hake, landed monthly from the statistical area " S.E. of Ireland " (Chart 13, " S.E."). Data in Appendix, Table XV.

The monthly mean temperature of the sea-surface at dawn at Coningbeg Lightship and at the Seven Stones Lightship respectively, during the same period. Data in Appendix, Tables XVI and XVII.

the shoal water between the months of December and March (see Figures 12 and 13), and these are only occasional small catches taken by trawlers working for rays, &c.

Even these hake, however, take to pelagic food as soon as this becomes available. I have an interesting record of this. In March, 1925, off the Saltees, hauls with a headline townet showed that the Euphausiid *Meganyctiphanes* was rare or absent, and it was absent from the stomachs of small hake taken in the same hauls, which were feeding on bottom forms, as described in the previous paragraph. In the Channel, 22 miles south of the Saltees Islands, on the same day, a headline townet took 14 specimens of *Meganyctiphanes* in a 5-hour haul, but the small hake taken in the same haul had accumulated 54 specimens in their stomachs, against only 13 specimens of other species.

Mr. G. P. Farran kindly informs me that "the south and south-west coasts (of Ireland) are normal feeding grounds for very small hake at all seasons. The food, up to 20 cms. is mainly crustacea, chiefly *Meganyctiphanes norvegica* and *Crangon*, and above that size fish, usually Gadoids and Clupeoids when they can be recognised."

In section O reasons will be brought forward for believing that, in the case of small hake in the more typical hake areas, the seasonal movements may be partly controlled by the movements of the larger planktonic forms which directly or indirectly form their food.

Gadus Poutassou.—In view of the great importance of the blue whiting as food for the hake during the deep-water phase of the fishery, it is well to examine rather closely the food and feeding of this fish. The pelagic nature of its food was known to Smitt (1892), who states that it feeds on small herrings and sprats ; and Schmidt (1908) says definitely " it is in high degree a pelagic fish, even in the adult stages. We obtain an impression of this directly on examining the stomach contents ; these always consist of Copepoda and Schizopoda."

It has already been stated that the blue whiting is not usually found in the shallower and less oceanic waters, and its occurrence in the North Sea and Cattegat is that of an oceanic fish. I have not seen specimens further from the 100 fathom line than off Galley Head (in the south-western area) though it has been recorded off the Cornish coast. Dunn (in Day, 1880) says that " in June, 1861 our bays were full of the young of this species. In 1871, if possible, they were present in greater quantities, some shoals covering acres of sea water, these leaping over each other in their hungry haste to devour the young herrings which were plentiful in the sea."

During the autumn and winter the blue whiting seems to feed but little, and at this time the livers are remarkably large, filling a considerable part of the body cavity. The sexual organs are then also apparent to the eye, on opening the body cavity, as long, thin, hyaline bodies. The great size and fatness of the liver causes hake which have fed on blue whiting to have the gut full of a white fatty mass. The stomach contents of 170 fish examined in October, 1926, averaged only 0·7 grams per fish, whereas in July, 139 blue whiting contained, on an average, 2·6 grams of food per stomach. The food found in these 170 blue whiting, in October, may be tabulated thus :—

> Maurolicus, 4 specimens. Scopelus, 4 specimens. Small blue whiting, 3 specimens. Small gadiculus, 7 specimens. Cirolana, 1 specimen. Themisto sp. 2 specimens. Small Cephalopod, 1 specimen, and 65 grams of kril. The small extent of feeding may also be seen in Figure 21.

In February and March on the Westward grounds and below the Bull (Lat. 49° 30′ N. to Lat. 52° 50′ N.), blue whiting stomachs were empty in almost every case, the sexual organs were large and ripe, and spawning was obviously taking place.

In March and early April, blue whiting were found to be massing for spawning on the northern hake grounds, and in late April and early May were found specimens actually running with eggs as well as spent specimens. On the Rockall Bank in late April the fish were wholly spent. Thus, in blue whiting also there is a well-marked tendency for the spawning process to move north with the seasons.

In April in the south-western and western areas feeding is abundant. Kril is found in quantity in the stomachs in nearly every case, and the gadiculus, easily recognised by its small round otolith, with smaller blue whiting, was frequently taken also. It is during these spring months that the kril appears in vast shoals on the hake grounds on the edge of the deep water, and at these times blue whiting of all sizes feed heavily and exclusively on kril. But bottom living forms may be taken occasionally, and I have found in one instance a considerable quantity of these forms, including Pasiphaea and Pandalus, with Crangonids, such as Pontophilus and Cheraphilus, but especially the isopod *Cirolana borealis ;* it is as though a shoal of blue whiting may make an occasional raid on the sea-floor.

In May and June, as the fishery moves into shallower water towards the 100 fathom line, the nature of the food of blue whiting undergoes a change. It has already been mentioned, in the previous section, that at this time kril begins to

disappear from the stomach contents of small hake. It also appears much less constantly in the stomachs of blue whiting, which now feeds more on gadiculus and the smaller year-groups of its own species. Feeding undoubtedly reaches a high level at this time. Blue whiting taken inside the 100 fathom line, off the Blaskets, in May, 1925, were feeding exclusively on Euphausiids.

At this time also the blue whiting often disappears completely from the hauls, though present in the stomach contents of hake, but, in any case, one must expect very irregular appearances in a mid-water fish. In June it was impossible to keep a continuous record of the feeding of the blue whiting, for this reason, and it is likely also that, at this time, the blue whiting begins to move back over the deeper water away from the shallow waters in which hake is now being caught.

As kril tended to disappear from their stomachs the hyperiid amphipod Themisto began to appear in increasing quantity, especially in the smaller sizes of blue whiting. A typical sample of the stomach contents of blue whiting at this time (June, 1926), was found to contain :—

> 57 small blue whiting, 6 gadiculus, 3 specimens of Maurolicus, 3 small Cephalopods, and 11 specimens of *Cirolana borealis*.

In July, 1926, the gadiculus and kril had almost disappeared from the stomachs of blue whiting, but the small pelagic mid-water fish *Maurolicus pennanti* was very plentiful in the stomachs of both large and small blue whiting. I had previously found an occasional specimen in the stomachs of mackerel in Galway Bay in September, 1925, but in July, 1926, it had become a really important item of food. Many specimens of Maurolicus taken from the stomachs of blue whiting were in good condition ; their stomachs contained Copepods, chiefly Calanus and Acartia. A list of the larger constituents of the stomachs of a sample of blue whiting at this time (in Lat. 52° 20′ N. to Lat. 52° 40′ N., 120–150 fathoms) was as follows :—

> 39 small blue whiting, 2 small argentines, 158 intact specimens of Maurolicus, besides a considerable number of macerated specimens, and two small cephalopods.

Of the smaller planktonic animals easily the most important was the hyperiid *Themisto gracilipes*. This was present in enormous quantities in all sizes of blue whiting. An analysis of the stomach contents of large blue whiting gave the following weights :—

> Small blue whiting, 104 gms. Maurolicus, 38 gms. Themisto, 42 gms.

But here also strongly selective feeding was shown, for some of the blue whiting were found to contain nothing but the pteropod *Clio pyramidata*, which was otherwise rather rare in stomach contents.

The smaller blue whiting, which had an average length of about 15·8 cms., were feeding exclusively on Themisto. No less than 16 grams of pure Themisto were contained in 22 specimens, a wonderful quantity when the small size of the stomachs in these fish is considered.

Summing up the annual cycle in blue whiting, therefore, one may say that, from about April onwards to September, feeding is intensive, the liver is small, and the sexual organs very much reduced ; in the winter, feeding is slight, the liver very large and the sexual organs are ripening for the spawning act in February and March. The season is slightly later on the northern hake grounds.

Other forms.—The Gadiculus is by far the most consistent, in feeding upon kril, of all the hake's food-fishes. A considerable number of observations have been made at various times during 1925 and 1926 on the food of this fish, and it is clear that during the greater part of the year it feeds upon kril alone. During the early summer only has the gadiculus been found feeding on other forms. Thus in June, 1925, and in June and July, 1926, it was feeding almost entirely on Copepods. In June, 1925, in particular, the stomach-contents were almost pure samples of

Acartia, while in June and July, 1926, the Copepods concerned were chiefly Calanus and Acartia. It has already been noted that this is also the time when kril disappears from the stomachs of hake and blue whiting.

In May, 1925, as many as 12 large specimens of kril were found distending the stomach of one small gadiculus, while in October, 1926, eight were found in one stomach.

The smelts (*Argentina silus* and *Argentina sphyraena*).—Of these forms *A. sphyraena* is certainly the less oceanic and inhabits shallower waters. Jenkins (1925) says: "the smaller species, *Argentina sphyraena*, has a rather more southern distribution, and lives in less deep waters than the large species, and is consequently found oftener in inshore waters." I have only two notes on the feeding of *A. sphyraena*, and both these refer to feeding on Euphausiids (see Hickling (1925), where *A. sphyraena* is wrongly referred to as *Osmerus eperlanus*). No doubt during the winter, when Euphausiids are few or absent in the shallower waters, the Argentines, like the small hake, turn to the bottom fauna for food; this might account for Edwards' record of small crustaceans and fragments of *Sertularia*, &c., found in the stomach of a specimen examined by him, and Scott's (1903) of *A. sphyraena* feeding on crustacea, starfish and annelids.

Argentina silus is usually found to contain a clear jelly-like mass in the stomachs. Holt (1897) noted this in a specimen; he says: "Œsophagus and stomach were filled with a mass of finely triturated organic matter, which appeared, judging from experience in similar cases, to be the muscular tissue of shrimps and prawns." These jelly-like masses are found in the smelts all the year round, and their true nature was suggested by the examination of a large number of fresh smelts in May, 1925. These were full of salps, many in a fairly fresh condition, and since then, traces of the typical structure of salps have been repeatedly noticed in the stomachs of smelts. I have therefore concluded that *Argentina silus* feeds mainly upon salps, but they may nearly always contain kril also, often plentifully, especially in winter, when also undoubted bottom living Amphipods may be found occasionally in the stomachs. During the spring and early summer the Pteropod *Clio* and the Hyperiid *Themisto* are also eaten to a considerable extent.

The Cephalopod *Stenoteuthis* seems to feed chiefly on other cephalopods, since specimens examined by myself have always contained the suckers, jaws, &c., of cephalopods. The smaller fantails *Todaropsis* and *Ommatostrephes* feed chiefly on fish, especially the gadiculus and the small blue whiting, to judge from the otoliths occasionally found in the finely divided masses in the stomach. But when the kril is abundant on the hake grounds, these fantails feed on kril to a surprising extent. On May 18, 1925, three specimens were found quite distended with fragments of *Meganyctiphanes*, very finely minced.

In section J it is stated that the hake off St. Kilda in January, 1926, were found to be feeding heavily on the squid Loligo. I have found Loligo feeding on kril to a surprising extent, up to 3 grams of kril being present per squid, in the Faroe-Shetland Channel.

Caranx trachurus.—Observations on the horse-mackerel have been confined to the summer months, when it is found most plentifully in both the deep and shallow water. Indeed, during the summer (in July, 1926, for example), the trawl may come up full of horse-mackerel, which is a serious nuisance, especially because the sharp spines on its back lacerate the hake and so lessen their value.

The horse-mackerel feeds mainly on small pelagic organisms, but it occasionally takes a fair quantity of small fish. During the early summer, when small blue whiting and Maurolicus are abundant, the horse-mackerel feeds on these to some extent, but its chief food is the kril, with the pteropod *Clio*, *Themisto*, and, much more rarely, salps.

In May, kril is by far the most abundant article of food, and great quantities are often found in the stomachs of horse-mackerel, especially late at night, so fresh that the luminous organs are still shining.

In June, in the deep water, *Themisto* and the pteropod *Clio* commence to take the place of kril, and in July very little kril is to be found in their stomachs, which now contain chiefly *Clio*, *Themisto*, and the fishes *Maurolicus* and small blue whiting.

Specimens taken in very shallow water (38 fathoms) off the Saltees Islands in July, 1925, were feeding on Copepods, Podon, &c., but in October, 1924, off the Smalls, they were found feeding on Euphausiids (Hickling, 1925).

N. Plankton Movements and the Seasonal Migrations of Hake.

A study of the food and feeding of small hake, blue whiting, gadiculus, smelts, horse-mackerel, &c., gives a considerable amount of information about the movements of the most important pelagic organisms. Kril, Salps, Pteropods, *Themisto*, and *Maurolicus* seem to pass over the hake grounds in more or less regular waves, beginning with kril in early spring, and ending with *Themisto* and *Maurolicus* in the summer. Each wave of plankton is marked by a time of selective seeding on the part of some or all of the fishes studied. General notes on the food of the chief food fishes of the hake have been given in the preceding section, and they will be summarised here, because they seem to throw some light on the movement of immature hake into the shallower waters, and of all classes of hake into the North Sea.

This movement of pelagic forms has been noted frequently as the result of work on Plankton. Thus Kramp (1913) indicates that there are distinct seasonal variations in the abundance of kril in the southern Norwegian Sea, and northern North Sea. "In May, when it is not specially numerous in the southern part of the Norwegian Sea and the Faroe Channel, it is completely wanting in the North Sea except at one station at Bergen and once near the Orkneys. In August, when numerous in the Norwegian Sea and Faroe Channel, only a few specimens were taken in the North Sea. . . . In November, it is taken more or less frequently, partly in the N.W. part of the North Sea, partly off the S.W. coast of Norway."

My own notes on the seasonal variations of kril apply to the south-western area only. They were made between October, 1924, and October, 1926, and may be summarized thus :—

In October kril are abundant in the shallow water off the Smalls, and on the south-west banks (Hickling, 1925). They are also present on the deep-water grounds to the west of Ireland and on the Porcupine Bank (Long. 14° 20′ W.). But in January, while still present in the deep water, they are rare in the shallow water, and the same areas which yield abundant kril in October now give very few specimens, or none at all. In March kril is very abundant on the westward grounds (Lat. 49° 30′ N., and thereabouts) on the grounds "below the Bull" (Lat. 52° 10′ N., and northward), in fact, at this time the kril commences to set in in a dense wave which is reflected in the great extent of feeding and selection of this organism by fishes. But in 50 fathoms off the Old Head of Kinsale, and in still shallower water off the Saltees, they are still scarce or absent. Small specimens are found in the stomachs of mackerel off the Old Head, but it is not possible to say if there are young kril or allied Euphausiid shrimps. Of these, *Nyctiphanes Couchi* is a distinctly shallow-water form which one would expect to find all the year round near the land. But in March, 1925, in the deepest part of the Irish Channel south of the Saltees, kril was found both in a headline townet and in the stomach contents of small hake. In April and May the wave of kril passes over the deep-water hake grounds, until in June and July they are rare in the stomach contents of fish taken on these grounds, but during the same months they appear in

quantity close inshore off the Blaskets, Skelligs, Fastnet, and in July are once more fairly plentiful off the Smalls, where they are the food of small hake and other fish.

A seasonal inward migration of kril is thus clearly suggested, which reaches its maximum penetration in October, when kril are most abundant in the shoal water, and a minimum in January to March when kril is rare in the shoal water. In March the tide of kril starts to flow once more into the shoal water.

Hyperiid Amphipods, of which *Themisto gracilipes* seems by far the most important, are present all the year round in the stomachs of fish taken on the deep-water grounds, but only in small quantities. Like the kril, however, they reach a sudden maximum at a time slightly later than the kril-maximum, in June and July, and then play for the pelagic fishes the part hitherto played by kril, which has now become scarce in the deep water. By September and October, however, these forms had once more become scarce in the stomachs of fish on the deep-water grounds. I made no catches or observations in the shoal water which would point to the presence of Themisto in anything like the abundance with which it appears in the deep water in July, or comparable with the abundance of kril in the shoal water in autumn.

Tattersall (1905), speaking of the west coast of Ireland, says that " there is distinct evidence of an inshore migration in late autumn, since, except in the late autumn and winter, *Parathemisto* is absent from both inshore townettings and the stomachs of fish caught near the land." Hence it would appear that the wave of hyperiids, which passes over the hake grounds on the edge of the deep water in June and July, reaches the coast of Ireland in autumn and (early) winter.

On the other hand, Tesch (1910) can find no evidence of a seasonal variation in the material collected by the International Council.

Salps and Pteropods are of little direct importance to the hake fishery, though both form an important part of the food of Argentines, and pteropods, at the time of their maximum abundance, of horse mackerel and blue whiting also. The important Pteropod is *Clio pyramidata*, which reaches its maximum in June and July, according to observations on stomach contents. Massy (1907) says that *Clio pyramidata* is common offshore on the west and south coasts of Ireland at all seasons, but that the greatest number of records are from the period April to September.

Salps, though of even less importance than the Pteropods to the hake fishery, are especially worth considering in connexion with the seasonal variation of pelagic organisms. Their migrations are well known. Schmidt (1908) describes their penetration into the Norwegian Sea, and shows how, while in May they are restricted to the Atlantic, in July and August they are found invading the Norwegian Sea, until in autumn they are found right in at the coast and in the fjords of Norway.

On the Irish deep-water hake grounds, salps appear in April and May, reaching a maximum in the latter month, and vanishing in June and July. (This refers especially to the regions north and south of Latitudes 52° 30′ N. Long. 11° 50′ W., and north and south of Latitude 51° 0′ N. Long. 11° 10′ W.). At the time of their maximum abundance they may be a serious nuisance, for they occur in myriads near the surface in calm weather, and at once fill up a plankton net, while they so clog the meshes of the trawls that, at times, it is necessary to work the port and starboard gears alternately in order to dry off the " sludge " in the sun and wind.

These observations agree with the data examined by Apstein (1910), where the salps usually appeared in the ocean off the south-west coast of Ireland in May. He shows, on a chart, how the Salps seem to migrate north around Scotland to Norway and the North Sea, and south and west into the English Channel. He says that the salps travel on the currents of the Atlantic stream, but this statement argues

that there must be distinct seasonal variations in the flow of these currents to account for a seasonal wave of salps.

Storrow (1925) rightly points out that such a movement as the drift of salps cannot be explained in terms of differences in salinity and temperature, and suggests that there are other factors associated with oceanic water which we do not yet know. In any case, the presence of salps in such areas as the North Sea is usually taken as an indication of the presence of oceanic water, and on such occasions salps usually make their appearance there in the autumn.

Finally, *Maurolicus Pennanti* itself, which is a small pelagic fish with luminous organs, seems to exhibit a seasonal variation which may be considered a migration. It appears in the stomachs of blue whiting in great abundance in June and July beyond the 100 fathom line, for example, in 1926, in Latitude 52° 30′ N. and thereabouts, but it is no longer eaten in quantity by the blue whiting in September, in this region. But I found it there in the stomachs of mackerel in Galway Bay. Holt and Byrne (1912) say that "Maurolicus is normally a denizen of about the upper 400 fathoms of the open sea, and may occur on and near the bottom shoreward of the 400 fathom line. Comparatively frequently, however, as appears from the records collated by Day (1880) and Smitt (1892), adults wander, even in some numbers, to the shores of north Europe, where they have often been found cast on the beach." The cases recorded by Day and Smitt almost all occurred in winter. Therefore it seems that in Maurolicus, also, there is a shoreward wandering at the close of the year.

Summary of the Movements of Food Organisms.

Kril.—The inward migration towards shoal water begins in March, reaches a maximum in shoal water in October, and then falls off until the minimum is reached between January and March.

Hyperiid Amphipods.—Become abundant on the hake grounds on the edge of the deep water in June and July. Reach the Irish Coast in autumn and early winter.

Pteropods.—Appear on the deep-water hake grounds in May, and reach a maximum in June and July.

Salps.—Reach a maximum on the hake grounds in May. Disappear from the hake grounds in July, but migrate east and north to the English Channel and to Norway and the North Sea, which they reach in late autumn.

Maurolicus Pennanti.—Appears on the hake grounds west of Ireland in June and July; occurs in Galway Bay in September, and is cast ashore, often in some numbers, chiefly in winter, on the north-east coast of Scotland and elsewhere.

These notes on seasonal variations in the abundance of five typical oceanic mid-water organisms indicate that there is a general movement of oceanic forms into coastal waters towards the end of the year. On the evidence offered by the movements of salps and kril, it seems that the inward wandering coincides with the penetration of Atlantic water of high salt content. Matthews (1913) states that maximum salinity is reached in November off the south-east coast of Ireland, and his charts illustrate the penetration well. Farran and Spicer (1923) find an autumn maximum in the salinity of the sea-surface waters at the Coningbeg Lightship (off the South-east coast of Ireland), and le Danois (1923), in describing the general annual pulsation of the Atlantic waters, states that the wave of salt water reaches the south-western area in July, and commences to withdraw in November. In the south-western area, therefore, the oceanic waters have their maximum penetration in the late autumn, when also, apparently, the oceanic organisms wander into the fresher coastal waters.

In many respects the penetration of hake, which may be regarded as a typical Atlantic oceanic fish, closely resembles this inward, and probably passive, wandering of the smaller oceanic organisms.

O. The Penetration of Hake into Shallow Waters.

The seasonal changes in the distribution of hake have been fully described in an earlier section. Charts 1–12 and Table II sum up the position, which may be stated thus, in general terms. During the winter months hake are confined, for practical purposes, to the shelf area bordering the edge of the deep water, chiefly beyond the 100 fathom line. Little hake is found in the shallower waters inshore of the 100 fathom line at this season.

On the other hand, in the summer there is a well-marked inward movement of hake, so that hake may be caught in good quantity in water as shallow as 40 fathoms, as well as in the deep water. This annual invasion of hake may be studied with advantage by considering the statistical area " South east of Ireland " (Chart 13, " S.E.".) This area lies wholly within the 100 fathom line, and its shoreward limits roughly bound the area of penetration of hake in that region.

The quantities of hake landed from this area are given in Figure 13 (Appendix, Table XVIII), in which the monthly landings are plotted. The data were supplied by the Statistical Section. It is seen that during the winter months there is very little hake to be caught in this shallow water area. Such hake as is landed has been caught by trawlers fishing mainly for rays, &c. In certain places, such as between the Banks (Jones, Cockburn, &c.), off the Old Head of Kinsale, and especially in the muddy trough off the Smalls, two or three baskets of hake, chiefly small hake, may be taken in each haul. For example, during a ten day trip in January, 1925, on a small trawler, working between the Banks (Jones and Labadie in this case) and off the Old Head of Kinsale, 14 kits (24 cwts.) of hake, all small hake, were caught (*Macaw*, Capt. Rumble).

In the summer, however, there is often a good quantity of big hake caught in the shallow water area, for example, off the Old Head of Kinsale in May and June, 1925, and off the Hook in July, 1925. Small hake are caught in great quantities between the Banks and especially off the Smalls in the autumn. For example, during a trip from Milford to the Smalls grounds, working on the edge of the herring trawling fleets in October, 1924, 55 kits (95 cwts.) of small hake, and two kits each of big and medium hake, were caught in six days. The depths worked were between 47 and 67 fathoms (*Macaw*, Capt. Rumble).

It is a matter of experience that there is a sharply marked difference between the invasion of shallow waters by mature hake and immature hake. The trade categories " big hake " and " small hake " correspond sufficiently nearly to mature and immature hake. The big hake move in early in the year, between March and July in the south-western area, and rapidly scatter and disappear after spawning. This invasion of shallow water by spawning hake has been described in the section on a monthly cycle in the hake fishery.

On the other hand small hake collect in the shoal water in increasing numbers until a maximum is reached late in the year, in September or October. This difference between mature and immature hake can be demonstrated statistically.

Figure 12 compares the total quantities of big hake (mature hake) and small hake (immature hake), respectively, landed monthly from the area S.E. of Ireland throughout 1924, 1925 and part of 1926. It is seen that mature hake reach their maximum in June, and after this fall away rapidly to the winter minimum, whereas small hake are taken in increasing numbers until a maximum is reached in September or October. The full data are found in the Appendix, Table XV.

In Figure 12 there are also inserted curves which represent the mean monthly sea-surface temperature at the Sevenstones Lightship and Coningbeg Lightship,

respectively. For the former I am indebted to Mr. J. R. Lumby, who has calculated the monthly means with a five-day overlap to eliminate sampling errors; for the latter I am indebted to Mr. G. P. Farran, and the Irish Department of Fisheries, by whose courtesy I am allowed to publish them. The Coningbeg monthly means are based on observations at dawn at 10-day intervals.

The positions of Coningbeg Lightship and the Sevenstones Lightship are indicated in Chart 14, which also shows the main features of the area "S.E. of Ireland." The spawning regions visited regularly by mature hake lie along the 50 fathom line off Galley Head and the Old Head of Kinsale, on such knolls as lie in Latitude 50° 40′ N., Long. 9° W., and off Minehead and the Hook, in still shallower water (40 fathoms). The Smalls area, now so rich in small hake, though it was apparently a good fishing ground for big hake in earlier days, is the trough or gully

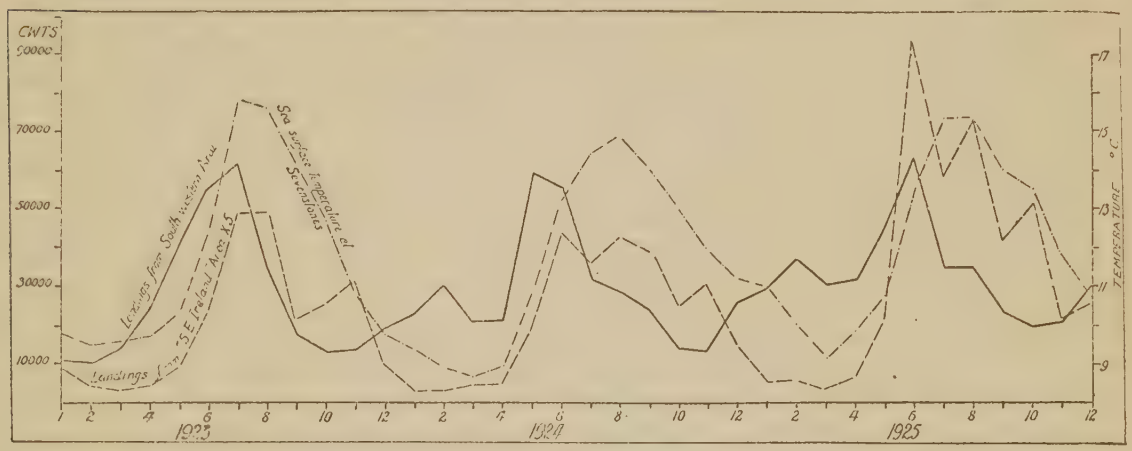


FIG. 13.—Catch of hake from the shallow-water area "S.E. of Ireland" compared with the catch of hake from the whole South-western area (Region 1, Chart 13). Data in Appendix, Table XVIII. The monthly mean temperature at Sevenstones Lightship for the same period. Data in Appendix, Table XVII.

marked in the Chart by the 50 fathom line, which runs north and east past the Smalls Light. This deep trough is called "the mud," because the bottom is of fine silt.

Figure 12 shows that there is a very close relation between the sea-surface temperature at Sevenstone Lightship and the Coningbeg Lightship, and the catch of small hake in the statistical area "South-east of Ireland."

Now, according to Matthews (1913), this area is flooded by water flowing in across the mouth of the English Channel between the Longships Lighthouse and Sevenstones Lightship. Part of the increase in temperature of the water in the area may, therefore, be due to warm Atlantic water poured in by the current flowing past the Sevenstones Lightship. The Sevenstones temperature observations afford an excellent indication of the temperature of this stream. But the mean surface temperature at Coningbeg follows the curve for the Sevenstones mean temperature very closely, with perhaps a slight lag which never amounts to as much as a month. Farran and Spicer (1923), who have worked up the temperature changes at stations on the coast of Ireland as far apart as the Fastnet Lighthouse and Skulmartin Lightship, find that the changes in temperature at these two widely separated stations "were sometimes simultaneous, or at any rate within the same ten-day period," and find also that the mean temperature curve for Skulmartin Lightship needs only retarding by one ten-day period to agree closely with the mean curve at Coningbeg Lightship, 150′ of Latitude further south. The rise of temperature at such stations as Coningbeg Lightship, and probably also at the

Sevenstones Lightship, to some extent, is associated with local heating from the land, a factor common to stations near the shore, over large areas; nevertheless, the mean monthly curves for the Coningbeg Lightship and the Sevenstones Lightship may be taken as a sufficiently close indication of the general warming up of the whole area between. The inward movement of the warm water is very well shown in the quarterly charts published by Matthews (1913).

The maximum catches of small hake, therefore, coincide closely with the time of highest temperature and greatest salinity in the south-western area, i.e., with the time of maximum penetration of oceanic conditions, so that to this extent the penetration of immature hake may be regarded as an inward wandering quite comparable to the general inward wandering of the other oceanic organisms.

It has already been emphasized that the penetration of mature hake is of an entirely different nature, being a visit early in the year for the purpose of spawning. It is interesting, therefore, to note that the curves for the catches of mature and immature hake rise together as the temperature of the sea-water rises, so that the first portions of the curves exactly fit. It suggests that, though the annual rhythms in the life histories of mature and immature hake are essentially different, they are forced into resonance by a common factor, namely rising temperature. Once spawning is accomplished, however, the mature hake shoals rapidly scatter, so that catches of big hake drop, and probably after a more or less brief feeding period in the shoal water, return to deep water beyond the 100 fathom line, thus disappearing from the area that has been discussed.

Returning again to Figure 13, it is now clear that the maximum quantity of all classes of hake are caught at a date between the maximum period for mature hake and the maximum period for immature hake in the shallow water area " S.E. of Ireland." The crests in Figure 13 are, therefore, slightly earlier than those in Figure 12. When the whole of the south-western area (Region 1, Chart 13) is considered, it is seen that the maximum is reached earlier for the area, as a whole, than for the shallow-water area alone, and also that there occurs in mid-winter a sharp rise in the catches, followed by another fall before the main summer rise in catches. With regard to the latter it can be seen that the secondary peak corresponds to the time when hake is scarcest in the area " S.E. of Ireland," and as this area may be considered typical of the shoal water generally, it seems very likely that the secondary increase in the catches, which occurs at the time when the hake fishery is confined to the deep water along, and beyond, the 100 fathom line, is due to a reinforcement of the numbers of hake by those fish which have withdrawn from the shallow water areas. The secondary peak is shown for all three deep-water hake regions (see Figures 3, 4, 5).

With regard to the earlier maximum for the whole south-western area, Matthew's charts (1913) of the temperatures of the sea, in this area, seem to offer an explanation. He shows clearly the inward movement of the isotherms during the spring and summer, so that the area warms up, generally speaking, from the deeper towards the shallower water. We have already seen that there is good reason to believe that the spawning migration of the hake is associated with the rising temperature during the spring months. At spawning, there is the maximum concentration of mature hake, consequently individual catches are highest, and the fishery, as a whole, is most profitable. Therefore, spawning on grounds outside the area " S.E. of Ireland " will tend to take place before spawning takes place within that area, if spawning follows the inward movement of the warm water which stimulates spawning. Since the quantity of hake caught in the shallow water area is only small compared with that caught in the whole south-western area, the maximum in the former only serves to cause a slight flattening of the falling curve for the whole area, so that the final result is that the maximum catches in the whole area occur earlier than those in the area " S.E. of Ireland." This tendency is

helped by the fact that, during the early months of the year, the great numbers of small hake are still fairly concentrated as they move in from the deep water, whereas later in the year they become scattered over the shallow waters, and this undoubtedly contributes to the rapid drop in the landings of hake for the whole area.

When the time of maximum catches of hake in the south-western area is compared with the mean monthly temperatures at Sevenstones, as in Figure 13, it seems that the maximum catches occur considerably earlier than the maximum temperature at Sevenstones. In other words, the wave of rising temperature on which the hake are carried to the most important spawning grounds has exercised its maximum effect in the area before it has moved in as far as the lightship. On the other hand, this wave influences the area "S.E. of Ireland" at approximately the same time as it reaches the Sevenstones, so that there is a much closer relation between the temperature curve at the Sevenstones and the catch of hake in the area "S.E. of Ireland."

The penetration of hake into shoal water is of two types. In a typical spawning area, such as the "S.E. of Ireland" region, there is a well-marked difference between the behaviour of big and small hake, so that, in their relation

FIG. 14.—The landings of big (mature) and small (immature) hake from the region "West of Scotland" (Region 3, Chart 13). Data in Appendix, Table XIX. Also fortnightly means of surface temperature at Monach Lighthouse. Data in Appendix, Table XXII.

to the temperature changes of the waters into which they penetrate, the big hake reach a maximum early in the rising slope of the temperature curve, whereas the small immature hake reach a maximum usually some months later, at the time of maximum temperature of the sea-water of the region in question. A further example of the difference of behaviour of mature and immature hake in a typical spawning area is to be seen in the "West of Scotland" area (Figure 14). Here, again, there is a distinct difference between the behaviour of big and small hake, as shown by the quantities landed throughout the year. As in the area "S.E. of Ireland" (Figure 12), the big hake reach a maximum considerably earlier than the small hake, though the curves are not as distinct as those of the landings from the area "S.E. of Ireland," because the area "West of Scotland" includes the deep water, where hake are taken all the year round, and there is therefore no such sharp rise and fall of the curves as in a shallow-water area which is subject to a definite annual invasion. Moreover, the mid-winter increase in catches, already referred to, introduces a confusing factor which apparently breaks up the regularity of the curves. According to Schmidt (1909), spawning takes place in the area "West of Scotland," for he says that "with a single exception, all the

pelagic young hake we have taken on the west and north of Scotland, as also off the Moray Firth, were found at the end of August or the beginning of September."

The mean monthly temperature of the sea-surface at Monach Islands Lighthouse, from such observations as are available, is also inserted in the Figure. I have to thank Dr. Bowman for his kindness in supplying these and other data.

On the other hand, in areas where the hake spawns little, or not at all, there is no such marked difference between the behaviour of big and small hake, which seem to enter and leave the region together in common relation to the temperature factor. There is no definite indication of spawning concentrations causing an early peak in the curve for big hake. Examples of this are furnished by the Irish Sea region and the North Sea. The penetration of hake, as a whole, in these regions is exactly similar to the penetration of immature hake into a typical spawning area.

Herdman, quoted by McIntosh (1912), has found spawning hake in April, south of the Isle of Man, and Birtwistle and Lewis (1924) state that from samples of the roes of hake caught off the Isle of Man during September, " gonad conditions indicate that this is a spawning period." On the other hand, a series of papers

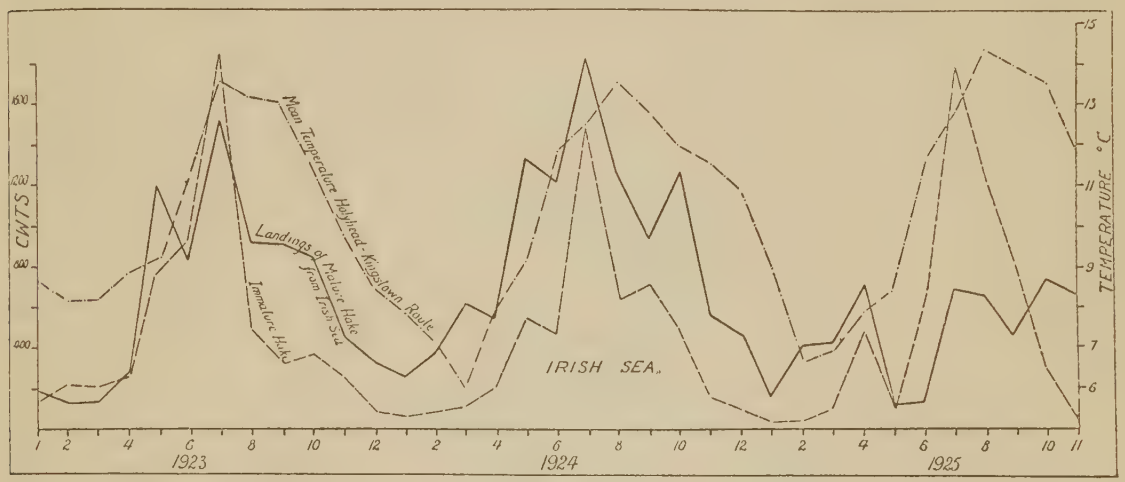


FIG. 15.—The landings of big (mature) and small (immature) hake from the Irish Sea region. Data in Appendix, Table XX. The monthly mean temperature of the sea-surface on the Holyhead-Kingstown steamship route. Data in Appendix, Table XX.

by Scott (1912, 1913, 1914, 1918) on the fish eggs caught in the Irish Sea, makes no mention of hake eggs, though these are characteristic, and fairly easily identified, and though the fish-egg investigations were thorough. It is legitimate to assume, therefore, that the Irish Sea is not a spawning area for hake to any important extent.

Figure 15 gives the landings, from the Irish Sea area, of big and small hake. It is seen that throughout the years 1923, 1924 and 1925 there is no marked difference in the behaviour of big and small hake, as indicated by the quantities landed. There is no early maximum in the landings of big hake, except, perhaps, in March and April, 1925, and the curves for big and small hake follow one another. There are, therefore, no definite indications of a spawning concentration distinct from the general rise and fall of the catches of both big and small hake. In Figure 15 is thrown a curve representing the mean monthly temperatures of the sea surface on the Holyhead–Kingstown steamer route. The data were obtained partly from the Bulletins Hydrographiques of the Conseil Permanent pour l'Exploration de la Mer; and, subsequent to July, 1925, I have used the unpublished data kindly supplied by Mr. R. J. Daniel. Between March, 1925, and July, 1925, there is a gap in the data. This gap has been filled by consulting the records

of the Liverpool Port Meteorological office, by the courtesy of Lt.-Com. Cresswell, R.N.R.

It is seen that there is a close connection between the mean sea-surface temperature between Holyhead and Kingstown and the catches of big and small hake in the Irish Sea. There is an anomaly in 1925, when the annual " peak " in the landings of hake, which extends from April to October, is completely missing. It is impossible to explain this discrepancy, but apart from this, one can say that there is a good correspondence between the curves for big and small hake, and that the catches of hake in the Irish Sea are closely associated with the mean temperature of the surface waters of the southern part of it. There is a distinct lag, however, so that the catches of hake tend to increase before the temperature shows a distinct rise, and commence to fall before the mean sea-surface temperature falls.

Figure 16 shows the landings of big and small hake from the " Northern North Sea " region. The curves for big and small hake are seen to correspond exactly,

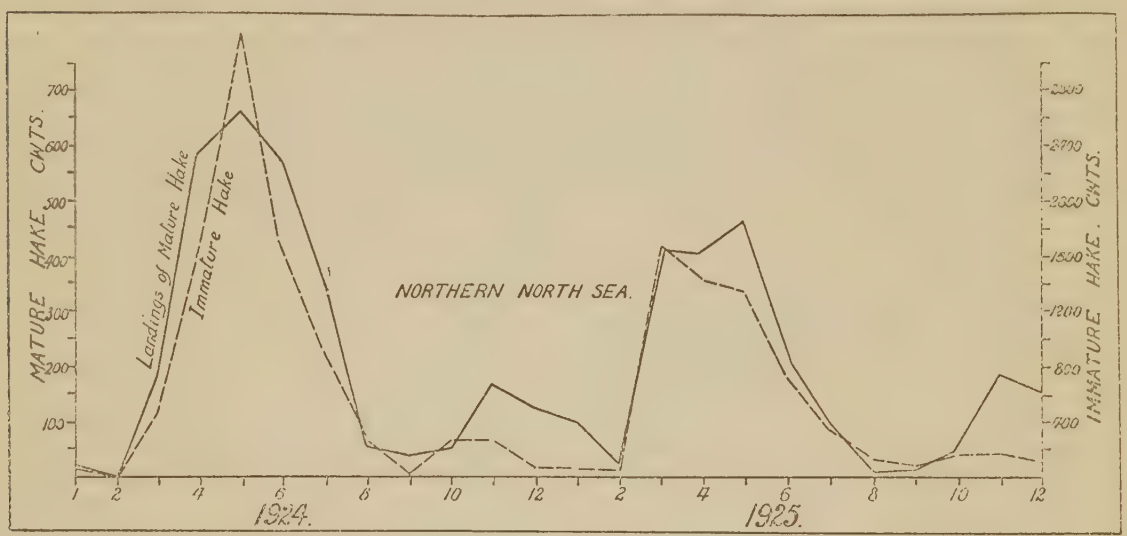


Fig. 16.—The landings of big (mature) and small (immature) hake from the " Northern North Sea " region (Regions 5 and 6, Chart 13). Data in Appendix, Table XXI.

so that there is no sign of any difference in behaviour between (presumably) mature and immature hake. Exactly the same relationship can be demonstrated statistically for the Middle North Sea region.

All writers seem agreed that the North Sea plays only a very unimportant part as a spawning ground for hake. Indeed, Damas (1909) states that the hake does not reproduce intensively to the east of the British Islands. Smitt, however, (1891) describes the spawning of hake on a small bank in the Cattegat, Schmidt (1909) records the capture of a large number of post-larval hake in the Skagerak west of the Skaw, and Ehrenbaum (1909) states that spawning takes place to a slight extent on the neighbouring North Sea banks, such as the Little Fisher Bank and the Outer Jutland grounds.

McIntosh (1912), however, states that no spawning hake have been procured in the trawling expeditions of former years, or since, in Scottish waters, though he records the capture of a female hake, 30 inches long, in the salmon stake-nets off the East Rocks, St. Andrews, on the 4th of July, 1911, whose ovaries were well developed, portions being so ripe that the transparent eggs issued readily from the reproductive aperture. Bowman (quoted by Howell, 1921) " has never seen a

female hake, with the eggs in the ovaries fully developed and ready for extrusion, landed at Aberdeen," though "the invading hake are all well-grown fish, with maturing sexual organs."

The problem of the invasion of hake into the North Sea is of great theoretical interest. Thus Henking (1905) says: "it is probable that it comes from the north, where it is more frequently caught. Whether the hake, so far as large quantities are concerned, may be considered a stationary inhabitant of the North Sea, may be doubted. The notion of an emigration on a large scale has greater probability. . . . We may picture how the first shoals quickly spread over the plateau of the northern North Sea, and appear in the Skagerak and Cattegat in dense masses in June . . ." He says further, that it possibly wanders back to the Atlantic in September, and points out that there is a second increase in the catches later in the year, as if the fish were on the return journey. He also states that the hake occurs in the catches of the North Sea trawlers only as well-grown fish, a fact which goes strongly against the idea of breeding grounds in the North Sea, but which points definitely to a migration.

Ehrenbaum (1910) also suggests that hake enters the North Sea as a migrant, but is not a true North Sea fish. Le Danois (1921) describes the entry of hake into the North Sea as "migration of dispersion," for feeding purposes, of those hake which have spawned to the west of the British Islands. He says that the hake enters the North Sea in June, between the Orkneys and the Shetlands, that part of the shoal follows the east coast of Scotland, where it attains a maximum in July and August, and that another group passes to the west of the Great Fisher

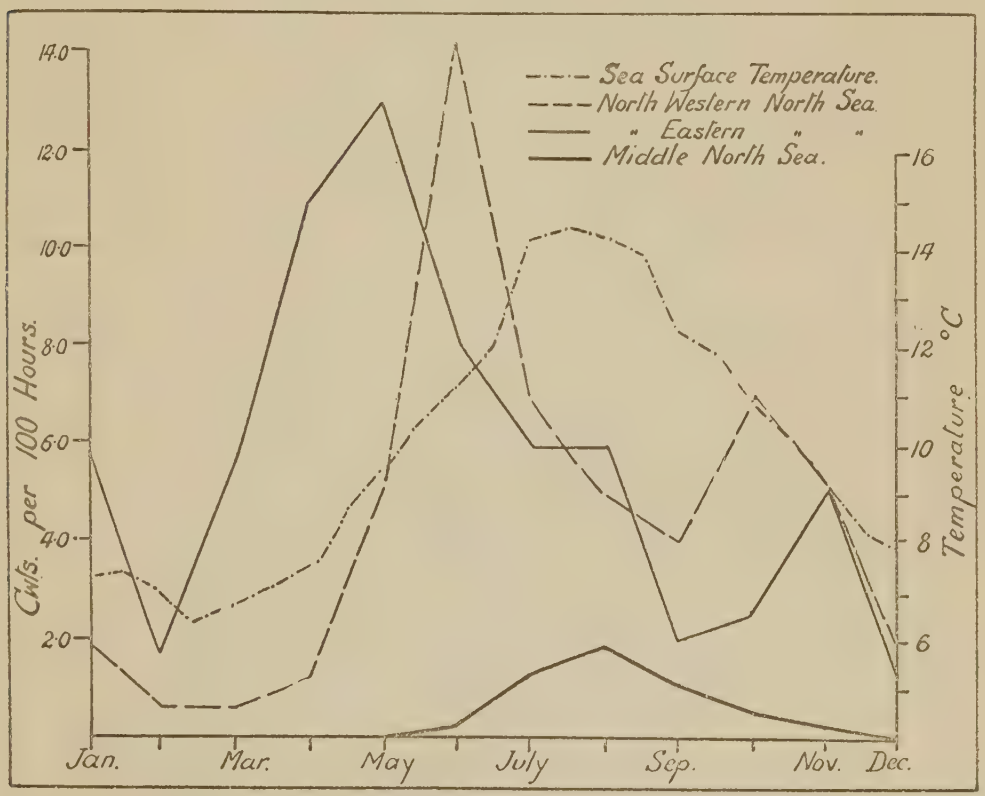


FIG. 17.—The mean monthly catch of hake in cwts. per 100 hours' fishing, in Regions 5, 6 and 7 (Chart 13), for the period 1923, 1924 and 1925. Data in Appendix, Table V.
The mean fortnightly surface temperature at Fair Isle Lighthouse, for the period 1923, 1924 and 1925. Data in Appendix, Table XXII.

Bank and the Witch Ground. From July onwards, he says, the hake is spread over the southern part of the North Sea, where it is caught in large numbers, especially in October. From then onwards the hake begins to leave the North Sea, and is seen making the return journey via the Middle Grounds and the Orkneys.

Fishermen to whom I have spoken have told me that the hake is such a rarity in the North Sea proper that specimens are put aside as curiosities! In any case, as Charts 15 and 16 show, over the south-western and southern parts of the North Sea the catch of hake amounts to less than half a cwt. per 100 hours' fishing. This represents a total of about 30 small hake (say one basket full) or 10 medium hake per 100 hours' fishing; so that one may hardly say that the hake is caught in large numbers in the North Sea proper. An endeavour will be made, in this section, to explain the distribution of hake in the North Sea.

In Figure 17 are drawn curves representing the mean monthly catches per 100 hours' fishing in the three North Sea regions shown in Chart 13 (Regions 5, 6 and 7). The data are to be found in the Appendix, Table V.

Regions 5 and 6 show a double annual crest somewhat similar to the double crests shown in Figures 3 and 4. Their explanation is fairly obvious when the catches in the third region, Region 7, are taken into account. The drop in catches between June and October in the northern areas is associated with a sharp rise in the catches in the middle North Sea. Though the quantities of hake caught in the middle North Sea are never great, when the great extent of the area over which they are distributed is taken into account, it will be understood that these quantities represent quite sufficient numbers of hake to account for the drop in the catches in the northern areas.

Figure 17 also shows that the spring increase in catches in the north-eastern North Sea (i.e., the deep-water portion of the North Sea, charts 13 and 17) is earlier than in the north-western North Sea, and that the autumn decrease in catches takes place earlier in the north-western than in the north-eastern North Sea. It appears, therefore, that hake enter the North Sea first from the deep-water channel off the Norwegian coast, and move south and west over the shallower waters into the middle North Sea region. They are reinforced slightly later by hake which enter the North Sea between the Orkneys and the Shetlands (see Charts 1, 2 and 6).

D'Arcy Thompson (1915), dealing with the statistics for the catch of hake by Aberdeen trawlers, remarks on the beautiful regularity of the curves for the catches in given areas of the northern North Sea in successive years. He gives it as his opinion that "whatever the precise route may be which the migrating hake follows, it is not such as would lead the fish close round the north of Scotland from the neighbourhood of the Minch to the neighbourhood of Shetland. The evidence, so far as it goes, rather entitles us to think that the hake, coming in from farther to the westward, arrive almost simultaneously in these two regions, namely, the Shetland region and the region north of the Lewes, and that their course is directed in some years more abundantly to the one, and in some years to the other."

In the early months of the year (March and April) hake is occasionally struck in moderate quantities west of the Orkneys and the Shetlands, off Foula and off the Noup. These hake are probably concentrated to feed on the herrings which congregate for spawning off the Shetlands at this season, and these hake do not, apparently, occur in sufficient quantities, nor consistently enough, to attract trawlers out for hake alone.

When the hake withdraw from the North Sea at the close of the year, the catches of hake in the middle North Sea fall as the catches of hake in the north-western North Sea rise; next, the catches in the north-western North Sea fall as those in the north-eastern North Sea rise; and finally both northern North Sea areas show a decline in catches as the hake also disappears from the middle North Sea

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(Figure 17). The hake certainly withdraw, to some extent, through the channel between the Orkneys and the Shetlands (Charts 3, 7 and 11), where there are at this time regions of slightly higher concentration indicating the slight crowding together of the fish on their outward migration. It is probably, like the general invasion of shallow waters by the hake, a question of temperature. At the close of the year, when the hake withdraws from the shallower parts of the North Sea as the temperature falls (Figure 17), it first moves out both through the channel between the Orkneys and the Shetlands, and between the Shetlands and Norway, but as the temperature in the former falls the outward migration becomes confined to the Norwegian Channel alone. It has already been pointed out that non-spawning hake enter and leave shallow waters in relation to the temperature of the sea.

But when the hake withdraw from the North Sea proper, they do not all migrate back towards the Atlantic, for, at the time when the distribution of hake in the North Sea is scantiest, the catches in the Norwegian deep water become high, indicating a definite concentration in that deep water. This is especially well seen in Charts 5 and 9, where, in March, 1924, and March, 1925, there was a sufficiently great concentration of hake in the deep water off the Norwegian coast to give catches as high as were to be taken in the west coast fisheries. This has been described in section E. It has already been pointed out that, for the whole of the hake fishery, the withdrawal of the hake to the edge of the deep water from shallow waters during the winter months causes a sharp rise in the catches at this time.

In fact, the evidence points to a sharp discontinuity in the distribution of hake in the most northerly regions of the fishery. There is, on the one hand, the main Atlantic stock, and there is also the isolated stock of hake which winters in the Norwegian deep water. This discontinuity was shown in a very practical way during the exploratory voyages of the *Florence Brierley* of Fleetwood. There is, on the evidence of the statistics, a considerable invasion of the North Sea, during the summer months, by hake from the Atlantic stock, but, as pointed out in an earlier paragraph, the first increase in catches takes place in the *north-eastern* North Sea, and only later spreads to the north-western North Sea. It seems very likely that these isolated hake may form, contrary to Henking's surmise (1905), a permanent "North Sea" stock. In the Norwegian Rinne a much lower temperature obtains (7° C.) than that which seems to limit the distribution of Atlantic hake (8·7° C.) and one might expect to find some statistical "racial" distinction resulting from this, if these hake indeed form a permanent "North Sea" stock. Future work, it is hoped, will test this point.

The fact that the hake is a deep-water species serves to explain, to some extent, the general distribution of hake in the North Sea. Charts 15 and 16 show the distribution of the hake for the years 1924 and 1925 in terms of catch per 100 hours' fishing. These charts agree with those published by Borley (1926) for the years 1923 and 1924, and, with the exception of the Norwegian deep water, which was apparently not exploited thus early, with the chart for the hake landed at Aberdeen, published by Thompson (1914). Chart 17 shows the depth contours for 50, 70 and 100 fathoms, and comparing the catch of hake, as shown in Charts 15 and 16, with these depth contours, it is seen that the general annual distribution is greatest in the northern and deeper parts of the North Sea, with an area of especially high concentration (up to 250 cwts. per 100 hours' fishing) in the Norwegian deep water region. In Chart 15, and in Borley's Chart 20, there is even an indication of an extension of hake into the southwardly-directed pocket of the 50 fathom contour line shown in Chart 17. Fulton (1903) notes that a number of Atlantic oceanic fishes, such as hake, saithe, ling, &c., were caught south of Fair Island, in 65 fathoms, in a locality only 80 miles from the 100 fathoms line, and suggests that the presence of the deep water, extending westwards as a submarine valley, influences the facies of the fish fauna.

On the other hand the average catch per 100 hours' fishing for the whole year also shows comparatively high concentrations of hake in the very shallow waters in the eastern part of the North Sea, west of Jutland. Reference to Charts 1–12 shows that it is about September that this concentration takes place. But Ehrenbaum (1910) points out that the eggs and larvae of the hake have been found in small quantities in this region in September (Jutland Outer Ground, Little Fisher Bank). This concentration, therefore, in the eastern North Sea represents all that the North Sea can show of a spawning concentration. The highest concentration indicated is apparently of an order less than 50 cwts. per 100 hours' fishing. It should be compared, for instance, with the fishing at the Melville Knoll, in 1925 (Chart 10), when the average catch was no less than 553 cwts. per 100 hours' fishing

With the exception just noted the concentration of hake within the 50 fathom line in the North Sea is almost everywhere less than 5 cwts. per 100 hours' fishing, and in the western and central portions as low as $\frac{1}{2}$ cwt. per 100 hours' fishing. The distribution of these very scattered wandering hake, however, bears an interesting relation to the current system of the North Sea, as determined by Böhnecke (1922), chiefly from a consideration of the salinity curves deduced from the data published by the International Council for the Exploration of the Sea between the years 1902 and 1914.

In the first section of this paper, where the seasonal changes in the distribution of hake were discussed, with the aid of Charts 1–12, it was repeatedly pointed out that there is an area free from hake extending in a north-easterly direction from the north-east coast of England. The average catch per 100 hours' fishing for the whole year, in 1924 and 1925 (Charts 15 and 16), also show this clear area very plainly, and Borley (1926) indicates it unmistakably in his Chart 19 for the whole year 1923. Now, Chart 18, after Böhnecke, shows the surface current system of the North Sea. It is seen that off the north-east coast of England, in the neighbourhood of the "clear area," the current flowing down from the northern North Sea divides, one branch turning back along the east coast of Scotland to form an eddy off the Firth of Forth, while the other branch runs south until it is deflected in an easterly direction by the current flowing in from the Straits of Dover. The region of this easterly deflection is the southern boundary of the distribution of hake (see Charts 15 and 16). In the central and western parts of the North Sea, therefore, the very few hake present seem to follow the course of the surface currents. This suggests that these hake are affected, directly or indirectly, by the drifting midwater organisms which are carried passively on the currents, for the hake itself is an active fish well able to force its way independently of water movements.

While these three factors, namely, depth, spawning and the current system, seem to account for general distribution of hake in the North Sea, the time of penetration, i.e., the factor which causes the seasonal movement into and out of the North Sea, is well worth further discussion. Henking (1905) associates the entry of hake into the North Sea with the inflow of Atlantic water of high salinity, an opinion shared by le Danois (1921).

Robertson (1909) describes the annual pulsation of the Atlantic waters entering the North Sea as varying greatly from time to time, and apparently subject to a periodical increase and decrease dependent on the seasons.

"A particularly scanty salt water distribution at the beginning of the year is normally followed by a vigorous Atlantic inflow which increases to a maximum towards the middle of April, when the whole north-western area of the North Sea becomes flooded by water of high salinity. Throughout May and June this powerful Atlantic influx apparently continues with but slightly abated vigour. From that season onwards, however . . . water of high salinity recedes farther and farther northwards towards Shetland, and a minimum is finally reached towards

the middle of winter, when the distribution of Atlantic water over this area of the sea is extremely limited." From Robertson's account, therefore, there would seem to be some justification for associating the penetration of hake into the North Sea with an inflow of Atlantic water.

But Thompson (1909) says that "as regards the surface waters the nature of the (annual periodic) fluctuation is such that we very generally find the highest salinities in late winter or early spring, and the lowest in summer or autumn" in the North Sea Basin. He further adds that in the north-western corner of the North Sea, between the Moray Firth and Shetland, there is clear evidence of a very different period, the highest salinities being here found between April and June and the lowest about November and December. The position is summed up by Böhnecke (1926), who concludes that the Atlantic water on its entry into the northern North Sea changes its period in such a way that the salinity maximum is shifted from early summer (May/June) to February, and a minimum is formed in August. While, therefore, Robertson's account of the seasonal changes in salinity holds good for the north-western North Sea, in the North Sea itself the maximum salinity is reached at the time when hake is scarcest, and the minimum salinity coincides with the time of maximum distribution of hake in the North Sea.

As a further ground for discounting the effect of water of high salinity on hake migrations, one may add that though, according to Robertson (1913), there were abnormal conditions of salinity in the North Sea during the winter of 1905–6, the summer of 1907, and the whole of 1908, during which year the distribution of Atlantic water was particularly scanty over the whole North Sea area, these abnormalities are not associated with any corresponding changes in the catches of hake in the North Sea as published by Thompson (1910). In fact, the year 1908, according to Thompson, was a slightly better year for hake than those before and after it, though there was a particularly scanty distribution of Atlantic water in that year.

Figures 12 and 15 show clearly that the temperature of the sea has a profound effect on the migrations of hake, and the same may be demonstrated less convincingly for the North Sea. There seems to be no convenient fixed station at which temperatures are taken from which data can be obtained for comparison with the catches of hake in the North Sea. For lack of better, therefore, I have in Figure 17 thrown in a curve (pecked line) representing the mean monthly surface temperatures for the years 1923, 1924 and 1925 at Fair Isle Lighthouse. From Figure 17 it appears that the migration of hake into the middle North Sea is closely associated with the rise of temperature of the sea during the summer months.

In the Irish Sea area also there is no relation between the salinity changes and the migration of hake into the area. Bassett (1912), in summing up the four chief types of oceanic circulation and their effect on the salinities of the Irish Sea, indicates that in two of the four cases the salinity maximum is reached in February, and in a third case not until May, in the Irish Sea. Matthews' charts (1913), based on the mean salinities observed at various stations between the years 1903 and 1912, show that, in general, the maximum salinity in the Irish Sea is reached in the winter, about February. Mr. R. J. Daniel informs me that his observations in recent years tend to confirm Bassett's work, but that the salinity changes are not at all sharply marked, in strong contrast to the great and regular seasonal changes in temperature with which the migration of hake into and out of the Irish Sea is so closely associated. Enough has been said to dispose of salinity changes as a factor at all comparable with that of temperature in governing the migrations of the hake.

The general effect of temperature on hake is different according to the condition of the fish. This has already been discussed. Mature hake which have been

undergoing a process of feeding and repair and, finally, ripening of the gonads in the deep water run in to the shallow water and spawn as the temperature rises in the spring. The spawning concentrations take place, apparently, over a more or less narrow range of temperature on the upward slope of the curve of rising temperature. Non-spawning and immature hake, on the other hand, show a steady infiltration into shallow water areas until the temperature commences to fall at the close of the season, when they pass back to deeper water. But in considering the penetration of hake into shallow water the depth limitations referred to earlier in this section must not be lost sight of. The hake is a deep-water fish which only penetrates to a slight extent into water shallower than, say, 40 fathoms, as Charts 15 and 16 show for the North Sea. The spawning of hake off the Hook in 38 fathoms in July, 1925, has been referred to, and hake are taken in small quantities at this depth by smacks off Plymouth, but, generally speaking, the 50 fathom line defines the limits of the hake fishery.

This difference in behaviour of spawning and non-spawning hake may be partly due to the profound changes in the volume of the different organs of mature hake at different periods of their sexual cycle, but it is also almost certainly due to an "intoxication-factor" associated with the ripening of the sexual organs. This is a hypothetical internal secretion, or hormone, which renders the fish very sensitive to external physical conditions. Schmidt (1906) expresses the theory thus: "Many fish at the spawning period are far more sensitive to external surroundings (depth, temperature, degree of salinity) than at other times, so that when about to spawn they often demand quite definite temperatures and depths, while otherwise, perhaps, and at other periods of their lives, they are able to live under quite different conditions." The same author (1907) discussing the life-history of the Iceland Cod, remarks that "the young . . . during growth . . . certainly roam about somewhat in the course of the year, but they are nevertheless able to stand the low winter temperatures of the north and east coasts, and thus show themselves very indifferent to external conditions. When maturity approaches, however, and the fish is preparing for reproduction, it becomes much more sensitive to external conditions. . . . The older fish, on account of their temporary great sensitiveness to external conditions, are driven together on relatively small areas, which must naturally be of the greatest importance for the fertilisation of the eggs, and, through this, for the persistence of the species."

As far as non-spawning hake are concerned, it is not possible to form any decision as to whether the fish come into shallow water with the oceanic drifting organisms mentioned at the beginning of this section, in response to a common physical factor, rising temperature, or whether the small hake set inshore in pursuit of the kril, on which it feeds.

Against the latter it might be urged that, for instance, in July, 1925, small hake were feeding in the shallow water (50–60 fathoms), chiefly on herrings and sprats; but in October, 1924, hake were feeding in the Smalls shallow water-area on kril; and it has been pointed out that in the North Sea hake tend to be distributed along the main currents, indicating a feeding, either directly or indirectly, on passively drifting organisms.

There are other recent examples of a relationship between water temperatures and the fisheries. Jee (1919) points out a relation between the total weight of mackerel landed on the south coast and the mean surface temperature in May. Harvey (1924) shows that there is a close relationship between the temperature of the sea at 5 metres depth, at a station 10 miles seaward of the herring grounds, and the mean weight of herrings per landing by steam drifters at Plymouth during the herring season. During the three seasons 1921–1922 to 1923–1924 it is shown that a high mean temperature is associated with a low mean catch of herring, while a low mean temperature is associated with a high mean catch, but the relationship

is obscured in 1924–1925, and Harvey rightly points out that the sea temperature is only one of many factors which may mask the effect of the one under examination.

P. Small-scale Concentrations of Hake caused by Local Abundance of Food.

The earlier literature repeatedly refers to the presence of hake in certain localities as a consequence of its pursuit of herring and mackerel. Pennant (1769) says that the appearance of hake on the Nymphe Bank twice a year was probably a consequence of its pursuit of shoals of these fish, and Donovan (1808) says that the hake "is of the migratory kind, frequenting our shores in immense numbers during the herring and mackerel seasons, appearing for the first time in June, and again in September, in pursuit of these fish." Yarrell (1836) notes that "it rarely happens that pilchards are taken in a sean without many hakes being enclosed with them." Thompson (1856) says that hake are caught with hand-lines on the Galway Coast, "but only when herrings are in the bay." Smitt (1892) gives evidence to show that the presence or absence of hake in the Cattegat may be related to the quantity of herring present in that area, and Ehrenbaum (1910) also suggests that variations in the hake fishery in the Skagerak are connected with variations in the appearance of the herring shoals.

Graham (1924) shows that abundance of food in certain areas of the North Sea may cause a local concentration of cod, but Hardy (1924) could find no relation between the abundance of herring food, as indicated by the number of fish found feeding, and the landings of commercial drifters. Bowman (1922), in describing the feeding of haddock on herring spawn, concludes that the spawning of the herring in certain localities may cause local concentrations of haddocks, distinct from the main autumn concentration of this fish, which is different in nature.

Blegvad (1925) finds a marked correspondence between the quantity of the shellfish *Solen pellucidus* and the catch of flat fish on a Danish fishing ground, and Davis (1923), as a result of his investigation into the distribution of certain shellfish on the Dogger Bank, was able successfully to indicate areas where bottom-feeding fish might concentrate.

But Schmidt (1926) gives a case which is very closely analogous to that about to be described for hake. "In the case of cod," he says, "the yield of the different hauls fluctuated considerably. This is probably connected with the fact that the cod were at that time seeking their food pelagically, and were constantly moving about in chase of the young sand eels (*Ammodytes*) which were there to be found. When our trawl passed through one of these swarms of sand eels we caught many cod, whereas the next haul, passing clear of the sand eels, would bring up few or none."

Ruud (1927) indicates an interesting relation between the distribution of kril and the catch of the whale *Balaenoptera physalus*, which lives almost entirely on kril, off the Norwegian coast.

I have already discussed the penetration of hake into the less oceanic water of the Irish Channel, the Irish Sea, and the North Sea, and have suggested that this penetration, which coincides with the spread of oceanic conditions, and with the penetration of oceanic floating organisms, may be partly a feeding migration in which the hake follows the oceanic organisms in their shoreward drift.

It has already been shown that the hake feeds heavily during its deep-water phase, and that, at that time, its chief food is the blue whiting. If, therefore, by analogy with the cases where hake is assumed to appear in certain localities in pursuit of herring and mackerel, the hake tends to be most plentiful in areas where there is abundant blue whiting, it should be possible, theoretically, to demonstrate a relationship between the quantity of blue whiting and the quantity of hake, in a series of samples from an area in which the shoals of hake and blue whiting can

move freely, and in which the trawl, moving through both rich and barren waters, tends to give a mean of many different conditions.

But the blue whiting is a mid-water fish, whose appearance in the contents of the trawl is quite fortuitous, the specimens which are taken having probably been caught during the hauling or shooting of the trawl. The numbers of blue whiting caught are no indication of their absolute abundance, so that it is not possible to make a direct comparison between the quantity of blue whiting and the quantity of hake in a given series of hauls.

It is also impossible to draw any conclusions from the quantity of food found in the stomachs of hake, for the uncertain factors controlling eversion make the evidence derived from small samples untrustworthy.

None the less, there was an unmistakable relation between the occurrence of blue whiting and the catch of hake on the exploratory voyages of the *Florence Brierley* from Fleetwood in March, April and early May, 1927. Hake clearly tended to be found in largest quantity where blue whiting were actually spawning, or ready to spawn. These hake, therefore, would form a feeding concentration, attracted by the breeding-concentration of blue whiting.

Now a study of the food-chain of the hake shows that its ultimate food consists chiefly of a fairly small group of oceanic mid-water organisms, of which the most important, perhaps, is the kril. It is an interesting and perhaps important point to examine whether by any means a relationship can be found between the local abundance of kril and the other organisms, and hake. The relationship would be not direct, of course, but by way of a food chain in which hake feeds on small hake, blue whiting, &c., and the latter feed either directly on kril, &c., or on small fish which have fed on kril, &c.

On a steam trawler it is plainly impossible to obtain a direct estimation of the quantity of ultimate food organisms by such methods as vertical hauls with special fine-meshed nets; and in any case, such a direct estimation would be by no means free from objection, because small fish and active crustacea such as the kril both can, and do, leap clear of a net (see Holt and Tattersall, 1905).

On the other hand an examination of the stomach contents of, say, blue whiting or small hake in a series of samples might furnish a useful indication of the abundance of ultimate food. For this purpose blue whiting is especially suitable, since its stomach is rarely everted, owing probably to its mid-water habitat, and its consequent freedom from the very great and sudden reduction in pressure which is experienced by hake hauled to the surface from deep water. It is also free, apparently, from the habit of disgorging its stomach contents on capture, which complicates work on the food of the hake.

Several series of observations have been made, principally with blue whiting. The data were obtained by collecting as many blue whiting as possible from a haul. The stomach contents were then dissected out, weighed, and examined. By dividing the total weight of food by the number of fish dissected, a mean weight of food per fish was obtained. This mean weight was then compared with the weight of big and medium hake, in cwts. (= boxes) per hour's fishing, taken in the same haul as furnished the blue whiting.

The weight of hake per haul is derived from the mate's estimate, which is usually fairly close. This estimate, in "boxes" of 8 stone (= 1 cwt.), is kept in a "tally" for the skipper's benefit. By dividing the number of boxes of big and medium hake caught by the number of hours of towing, the weight per hour's fishing is arrived at. By a coincidence, it happens that the weight of hake caught per hour, in cwts., is of the same order of numbers as the weight of ultimate food in blue whiting, in grammes, so that in the accompanying figures, with the exception of Figure 21, the same scale is used for cwts. per hour and grammes per fish. Full data are to be found in the Appendix, with details of the hauls.

The observations take the form of a series of isolated samples rather than a continuous record. There are too many difficulties, and too many disturbing factors, to make continuous observations possible. For example, it is plain that, to avoid error due to the vertical migration of hake on the one hand, and to possible variations in the daily intensity of feeding in blue whiting, analogous to the daily rhythm in hake, on the other, it is desirable to compare samples taken at approximately the same time of the day. In these observations, the hauls in the forenoon or afternoon are considered, principally the forenoon. It has also to be remembered that, especially on rough ground, the gear is frequently torn, and that often, for some reason, the trawl is not fishing properly, so that an abnormally small amount of hake is caught ; and that there is often not a sufficient quantity of blue whiting, in the catch on which to base a reliable mean figure for feeding. This has been the chief difficulty.

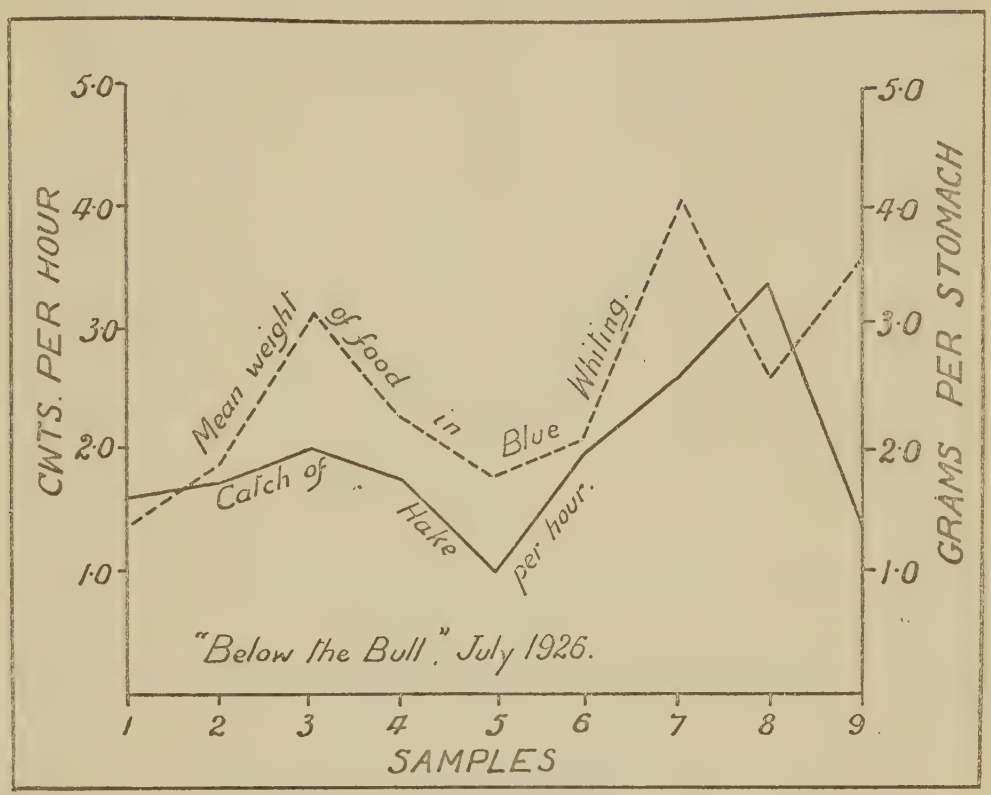

FIG. 18.—Apparent relation between the catch of hake in cwts. per hour of towing, and the mean weight of food per stomach, in blue whiting taken from the same haul. Data in Appendix, Table XXIII.

The method adopted of comparing samples taken, often at irregular intervals, is quite justifiable, because not only does each haul cover slightly different ground, but the effect of currents, tides and the active migrations of the organisms themselves, causes each haul to differ from those before and after it. If, then, there is any relationship between any two of these organisms, it should be possible to demonstrate it in a series of chance-selected samples.

The curve shown in Figure 18 shows a distinct tendency toward a direct relation between the quantity of food per fish, in blue whiting, and the catch of hake, in unit time, in the same haul. There are anomalies in samples 8 and 9, but the general tendency is for a direct association between a high level of feeding and a

high catch, and *vice versa*. It is noteworthy that the general level of feeding in blue whiting is high, the mean for the nine samples being 2·5 grammes.

It has already been mentioned that, during the spring months, the kril (*Meganyctiphanes norvegica*), which has been present in relatively small numbers on the deep-water fishing grounds throughout the winter, may appear in apparently vast quantities on these grounds, so that every mid-water fish and squid may be found feeding heavily and exclusively on it. Whenever selective feeding is taking place, it is a sure sign that food is plentiful; conversely, "the less abundant food is, the more kinds will be eaten" (Graham, 1924). At these times, when kril is, therefore, very abundant, one would expect to find that hake tend to collect in areas rich in kril. It was the similarity of distribution of kril and hake, which for waters south of the latitude of the Shetlands is remarkably close, and the

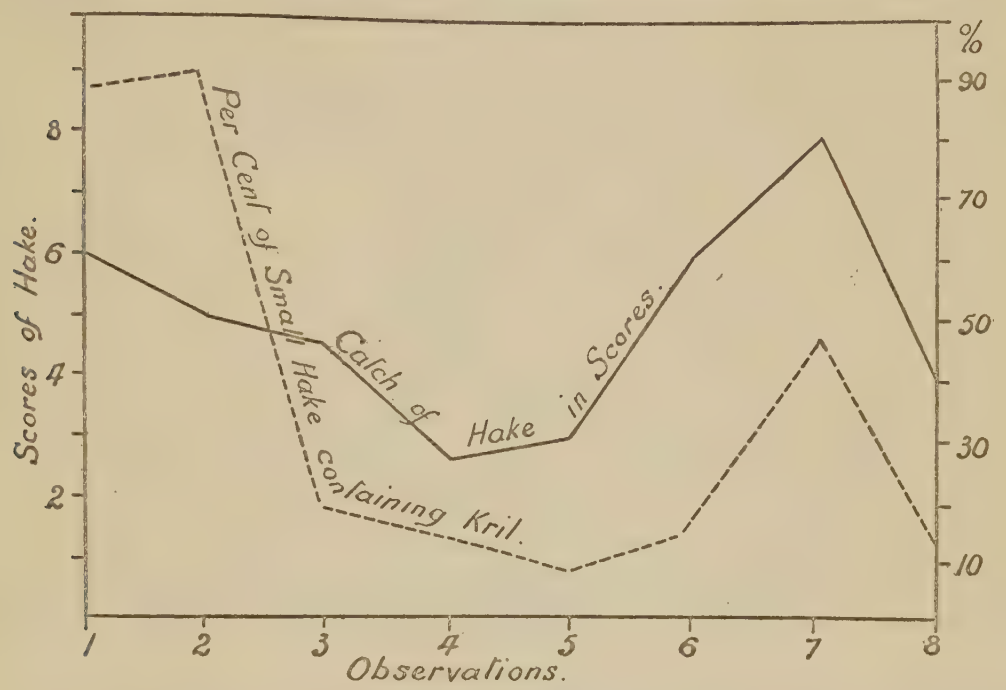

Fig. 19.—Apparent relation between the catch of hake, in scores, and the abundance of kril, as expressed by the percentage of small hake which contained it. Data in Appendix, Table XXIV.

frequent observations, during the course of my work, of the apparent selection of kril by hake, whenever possible, which led originally to attempts to correlate the abundance of kril with the catch of hake, and so to work on the whole food chain of the hake.

The shrimp *Meganyctiphanes norvegica* and its allies may occur in enormous shoals. I have recorded elsewhere (1925) the capture of upwards of 9,000 specimens of *Nyctiphanes Couchi* off the Smalls, in October, 1924, in a five-hour tow with a headline townet only 6″ in diameter at the mouth.

As a further example, in May, 1925, on the outer Fastnet ground, there was apparently a vast quantity of kril, for blue whiting contained it abundantly, up to 54 specimens per fish, and even the small fish Gadiculus contained 10 or 12 specimens each; while horse-mackerel, fantails, the Moleskin Shark (Spinax), the dogfish Pristiurus (containing up to 112 specimens), the Megrim and hake, up to 64 centimetres in length, were feeding heavily and exclusively on it. At this time, and in this area, fishing for hake was very good when clear going could be

found, but interruptions, due to splits on coral, made continuous fishing, and continuous records of the food and feeding of the blue whiting, impossible. For two days in succession every haul came up with the trawl split, and consequently with little or no fish. This may be quoted as an example of the difficulties encountered in practical fishing as well as the more special difficulties met with in the course of a series of observations of the kind to be discussed.

Three series of observations have been made. The first, in March, 1925, shows that there is apparently a relation between the quantity of kril, as expressed by the percentage of small hake which were found to contain it, and the quantity of big and medium hake taken in the same haul. The full data are given in the Appendix. As before, morning and afternoon hauls alone are considered in drawing up the graph in Figure 19 in order to avoid complications due to the effects of vertical migration and diurnal changes in feeding.

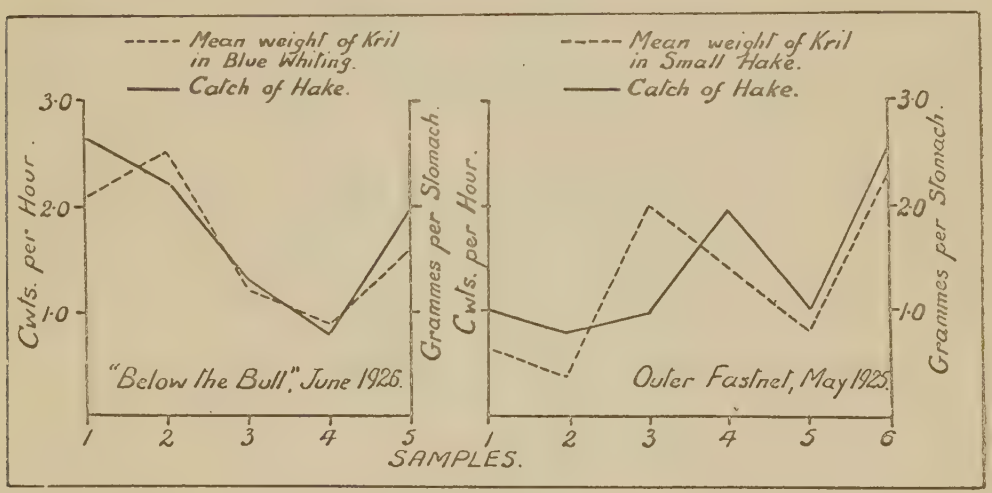

Fig. 20.—Apparent relation between the catch of hake, in cwts. per hour of towing, and the abundance of kril, as expressed by the mean weight of kril, per stomach, in blue whiting and small hake respectively. Data in Appendix, Table XXV.

But a much more reliable method of comparison is to be obtained by finding the mean weight of kril present per fish in blue whiting or small hake in a series of samples and comparing this weight with the catch of hake, per hour's fishing, in the same haul as supplied the small hake or blue whiting. This has been done, and in Figure 20 are given two graphs showing a relation between the catch of big and medium hake, in boxes (cwts.) per hour, and the mean weight of kril, in small hake, and blue whiting, respectively (using this weight as an indication of the abundance of kril). Full data are given in the Appendix, Table XXV.

From the curves in Figure 20 it is clear that there is here a simple and direct relation between the quantity of kril in a given area, as expressed by quantity per fish found in a small hake or blue whiting, and the weight of hake taken per hour's haul.

During these attempts to find a relationship between the quantity of kril and the quantity of hake there was an additional handicap, in that it often happens that small hake and blue whiting will feed on small blue whiting and gadiculus, which have in turn fed on kril, rather than directly on kril. But wherever this is the case it means that kril is less abundant since selective feeding is no longer taking place, so that the mean weight of kril per stomach still represents a figure of the same order of reliability as those based on exclusive feeding on kril.

So far, therefore, we seem to have a simple relation between the ultimate food of the hake and the quantity of hake, so that, on the evidence put forward, a locality rich in kril, &c., will become rich in hake. This need not necessarily be caused by an intelligent search for the richest food, but rather by the method of "trial and error." Hake which stray into the rich area find themselves among abundant food, and tend to remain there, so that there is an accumulation of hake in the locality, just as Bowman (1922) shows that the presence of herring spawn in quantity causes an accumulation of haddocks. Professor Johnstone and Mr. R. J. Daniel tell me that beds of very young mussels may cause a similar accumulation of plaice and that fishermen take advantage of the fact.

This accumulation probably tends to continue until a point is reached where, as Dr. Bidder points out (in Graham, 1924), there will be a constant relationship between the quantity of hake and the quantity of ultimate food. The locality then ceases to be richer than the average and ceases to attract more fish.

But very much more difficult to understand are the curves given in Figure 21. These are based on data obtained in the same way as those in Figures 18 and 20, and compare the mean weight of food per fish, in blue whiting, with the catch of hake per hour in the hauls which supplied the samples. The trips were made to the grounds below the Bull, and the Porcupine Bank, in June, 1925, and October, 1926, respectively.

In these curves there is an undoubted tendency towards an inverse correlation. There are anomalies in samples 5 and 6 from the second series of observations. In these cases, then, it appears, at first sight, that hake tends to accumulate where food is scarcest, but further analysis gives reason to believe that this is not probable.

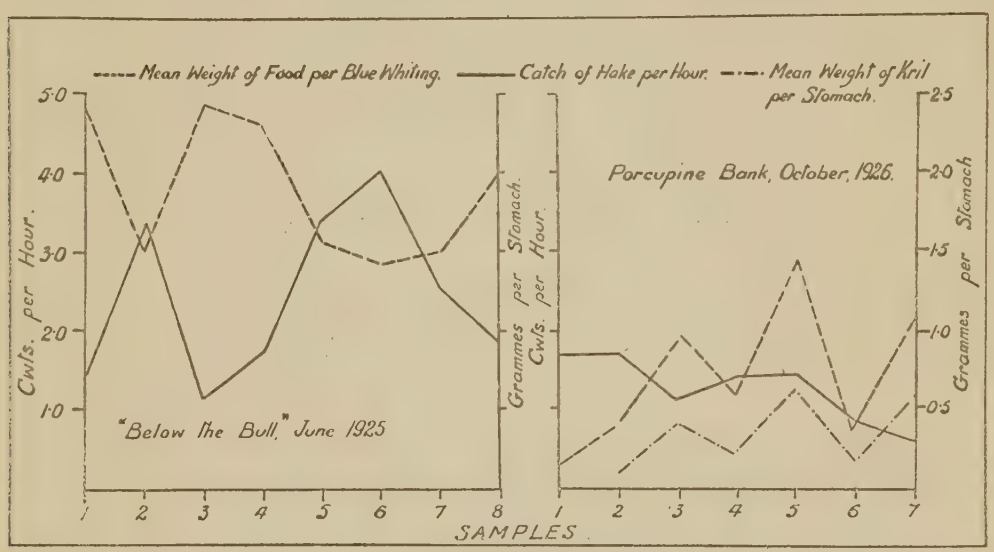
Mean Weight of Food per Blue Whiting.
Catch of Hake per Hour.
Mean Weight of Kril per Stomach.
Cwts. per Hour.
Grammes per Stomach.
Cwts. per Hour.
Grammes per Stomach
"Below the Bull," June 1925
Porcupine Bank, October, 1926.
SAMPLES

FIG. 21.—Apparent relation between the catch of hake in cwts. per hour of towing, and the mean weight of food per stomach in blue whiting. Data in Appendix, Table XXVI.

No absolute measure of the quantity of ultimate food has been attempted, and reliance has been placed upon the quantity found per stomach in such fish as small hake and blue whiting. This method may be fairly trustworthy where food is very abundant, as at times when selective feeding is taking place; but when ultimate food is relatively less plentiful, and the quantity of blue whiting relatively greater, another factor will be introduced. Hake, for example, will tend to follow the shoals of blue whiting, but, if the quantity of ultimate food is scarce in relation to the quantity of blue whiting, the latter will tend to "clean up" the water through

which it swims, so that, where blue whiting is most abundant, the quantity of food per fish will be least.

There are strong grounds for believing that fish will tend to accumulate where their most suitable food is abundant; in fact, this is generally accepted. Hardy's plankton indicator, for example (Hardy 1925), is based on this principle. In this direction it is worth pointing out that, in both cases given in Figure 21, in which there is a tendency to an inverse correlation, the quantity of food taken is comparatively low. The mean weight of food per fish in the eight samples from "below the Bull" in June, 1925, is 1·9 grams and in the seven samples from the Porcupine, 0·7 grams. But in Figure 18, in which there is direct correlation, the mean weight of the sample is relatively high, namely, 2·5 grams. In Figures 19 and 20 there is selective feeding on kril, which is itself an indication of the abundance of this organism. On the Porcupine (Figure 21), where there was, apparently, little kril and no selective feeding upon it, the mean weight of kril per fish is very low and varies directly as the mean quantity of all kinds of food. But it has already been pointed out that the intensity of feeding has a seasonal variation, so that, in any case, one would expect to find less food in blue whiting taken on the Porcupine in October than below the Bull in June.

The one fact which can be stated with confidence is that in areas so rich in kril that there is widespread selective feeding upon it, hake will tend to be most plentiful, with one reservation. It has been stated in the first section of this paper that the depth at which big and medium hake are caught depends upon the condition of the sexual organs. This is the controlling factor, and within it local concentrations of hake can be caused by local abundance of ultimate food. As an example of this controlling factor, in June, 1926, there was reason to believe that kril was very abundant, over 110 fathoms, on the grounds below the Bull, for a haul at this depth brought up a great quantity of horse-mackerel, each of which contained between 30 and 40 grams of pure kril, so fresh that the muscles were still transparent, and the luminous organs were shining in the mass. Yet the best fishing was found in 95 fathoms, many miles to the eastward, where the roes and milts were much further developed and feeding was less intensive. If, therefore, a concentration of hake can be caused by a concentration of food, it is only in so far as the physiological state of the fish will allow.

Great caution must, in any case, be exercised in considering this local effect of food abundance, for the general relation between hake and the ultimate food (kril, &c.) is not direct, but by a chain of three or four links. In the case of each link the feeding function is only one of many factors controlling the migrations of the organisms, and is a function that varies from season to season and possibly from day to day.

Finally, the quantity of food found in the stomachs of blue whiting is not above suspicion, for in October, 1926, I noticed on several occasions that blue whiting from the stomachs of big and medium hake contained abundant kril, where blue whiting from the catch contained but little. This would probably be the result of the different water layers in which the hake and the trawl respectively caught the blue whiting. In face of these difficulties I am surprised to find so distinct a relationship between the hake and its ultimate food as that which is revealed in the data discussed in this section.

Enough has been said, in the last two sections of this paper, to indicate the great importance to the hake fishery of the oceanic plankton and especially of the kril (*Meganyctiphanes norvegica*). A study of the life-histories of these forms might throw considerable light on some of the facts associated with the wanderings of the hake.

SUMMARY.

The hake is a deep-water species, which, at least at the present time, may be said to pass the greater part of its life in the neighbourhood of, and beyond, the 100 fathom line. It makes a seasonal invasion of shallower waters, however, the nature of which is different in spawning and non-spawning (and immature) hake. The seasonal changes in the distribution of hake are discussed in section B, illustrated by Charts drawn from statistical data, and are further considered in section O. They are summarized in section C.

In areas where the hake does not spawn intensively, big hake and small hake seem to migrate together in common relation to the temperature of the sea, so that the largest catches tend to be made at the time of highest temperature (section O). The changes in the salinity of the sea are discounted as a factor influencing hake migrations to an extent comparable with the effect of temperature.

The hake does not necessarily move into shallow waters to spawn, but when it does so, the big (mature) hake concentrate there comparatively early in the year, before the sea water reaches its maximum temperature, whereas small (immature) hake reach their maximum penetration into shallow waters, as shown by the catches, comparatively late in the year, at the time of maximum temperature of the sea. The catches of big hake, which must be greatest at the time of their concentration for spawning early in the summer (May and June), rapidly fall away later, and this decline is partly due to their scattering and partly due to their return to deep water. The sexual cycle in hake will form the subject of a future paper.

Immature and non-spawning hake are comparable, in their movement, with the general oceanic fauna of drifting organisms, which likewise reach shallower and less oceanic waters towards the autumn (section N). The different behaviour of mature hake is probably due to their special sensitiveness to external physical conditions at spawning time (section O).

During the winter months, when the temperature of the sea in shallower waters is low, the hake withdraws to the edge of the deep water, becoming concentrated there, so that catches become distinctly higher (section D). A number of factors, however, prevent this improvement in individual catches from affecting the total landings of hake to an appreciable extent, and the result of the movements of the hake is to cause a winter period of relative scarcity and a summer period of relative abundance (section A). Some of the factors contributing to the low level of the landings of hake in winter are discussed in section D, but the opinion may be repeated here, that a considerable part of the hake stock, at this time, is living freely in mid-water over the great depths.

A rise in the catches of large and medium hake, probably as the result of a concentration of mature fish for spawning, is said to take place at approximately monthly intervals, and the available statistical data seem to lend this some support. It is suggested that this is the result of a monthly period of activity in the reproductive organs of the fish, analogous with a similar phenomenon in many other animals (section F).

It is well known that, usually, there is but little hake to be caught in the trawl on the sea bottom at night, so that there is apparently a nightly migration vertically from the sea bottom. This is discussed in section G, and it is there suggested that

the migration is actually the result of a "sleep-rhythm" in the fish, which is inactive by day but active at night. This theory is supported by the facts that (*a*) it can be shown that the hake feeds at night, but not, apparently, during the day, and (*b*) the surface methods of catching hake, which are most successful at night, depend upon the hake actively seizing a hook or becoming entangled in stationary trammel-nets, whereas the method of catching hake on the bottom, which is most successful by day, depends upon the hake being swept passively into a trawl which may be moving very slowly relatively to the hake's own presumed speed of locomotion.

The hake feeds almost exclusively on a group of mid-water fishes and squids, and is apparently entirely independent of the bottom of the sea for its food supply (section I). The nature of the hake's food varies at different stages of its migration. In the (summer) shallow-water phase of the fishery the hake feeds mainly on mackerel and herrings, but during the deep-water phase of the fishery the blue whiting (*Gadus Poutassou*) is by far the most important species and may form 70 per cent. of the food of the hake (section K)

The hake feeds most heavily immediately after spawning and feeds but little when the roes become heavy at the approach of spawning (section L). A possible effect of this on the growth of the fish is suggested (section L).

A study of the food of the hake's food (section M) shows that the whole food-chain of the fish is independent of the sea bottom and, in the deep-water, can be traced down to a small group of oceanic planktonic organisms, of which the kril (*Meganyctiphanes norvegica*) is by far the most important. The importance of this organism is such that it is possible to bring forward evidence for believing that swarms of kril are able to cause local concentrations of hake, though only to a limited extent. One can also show a relation between the quantity of ultimate food in a given area, as shown by the quantity eaten by the hake's food-fishes, and the catch of hake (section P). Partly for this reason, and partly also because their wanderings may influence, on a large scale, the movements of hake, the importance of a study of the larger oceanic plankton organisms is emphasized.

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APPENDIX.

TABLE V.

Average catch of Hake, in cwts. per 100 hours' fishing, taken by Steam Otter Trawlers landing in Great Britain from each of the Regions 1—7 in Chart 13. Data supplied by the Statistical Section.

Region No.	1923.							1924.							1925.							Monthly Means, 1923–1924–1925.							Mean of all Years all Regions.
	1.	2.	3.	4.	5.	6.	7.	1.	2.	3.	4.	5.	6.	7.	1.	2.	3.	4.	5.	6.	7.	1.	2.	3.	4.	5.	6.	7.	
January ..	24	59	37	4	4	15	0·0	70	138	9	5	0·4	0·2	0·0	127	113	17	0·7	0·9	2	0·0	74	103	21	3·2	1·8	5·7	0·0	29·8
February ..	27	125	10	10	1	0·0	0·0	82	205	9	8	0·3	0·1	0·0	122	116	21	1	0·5	5	0·0	77	149	13	6	0·6	1·7	0·0	35·3
March ..	32	59	16	8	0·7	0·1	0·0	49	153	15	11	0·2	2	0·0	82	101	87	5	1	15	0·0	54	104	39	8	0·6	5·7	0·0	30·3
April ..	49	152	45	10	1	5	0·0	56	152	68	7	0·7	12	0·0	81	132	101	4	2	17	0·4	62	145	71	7	1·2	11	0·1	42·6
May ..	89	163	50	3	4	9	0·1	160	280	52	9	8	14	0·0	144	183	109	4	4	15	0·0	131	209	70	5	5	13	0·0	61·9
June ..	110	153	52	66	25	11	0·2	144	233	108	9	7	3	0·2	171	228	81	66	9	11	0·3	142	205	80	47	14	8	0·2	70·9
July ..	121	178	83	127	8	1	1	96	202	126	93	7	11	2	108	226	90	126	5	6	1	108	202	100	115	7	6	1·3	77·0
August ..	85	159	92	29	4	2	3	89	233	105	42	7	7	2	96	243	134	95	4	8	0·5	90	212	110	55	5	6	1·8	68·5
September	59	125	68	14	3	2	2	76	217	90	17	4	3	0·9	72	208	136	18	6	2	0·4	69	183	98	16	4	2	1·1	53·5
October ..	57	129	70	12	5	1	0·7	54	162	84	18	8	6	0·6	71	168	107	8	7	0·5	0·3	61	153	87	13	7	2·5	0·5	46·2
November	54	104	69	6	4	2	0·2	56	126	57	5	4	8	0·3	85	137	76	0·5	7	6	0·1	65	122	67	4	5	5	0·2	38·4
December	68	147	47	3	1	0·6	0·0	84	134	50	3	3	3	0·0	107	117	74	2	1	0·9	0·0	86	133	57	3	2	1·5	0·0	40·3

TABLE VI.

Mean monthly landings of Hake in England and Wales, with percentages of big and medium Hake, for periods 1908–1913 *and* 1920–1925. *Data from the monthly return of Sea Fisheries, published by the Ministry of Agriculture and Fisheries.*

Month.	1908–1913 Mean Monthly		1920–1925 Mean Monthly	
	Landings of Hake.	Percentage big and medium Hake.	Landings of Hake.	Percentage big and medium Hake.
	Cwts.		Cwts.	
January	33,236	72	29,395	41
February	37,486	74	34,303	43
March	39,880	71	39,300	50
April	63,552	75	54,594	59
May	128,272	79	90,263	64
June	111,601	80	103,398	64
July	109,006	80	103,160	63
August	77,422	72	104,023	58
September	55,314	69	70,620	53
October	39,242	68	56,682	46
November	35,117	64	45,146	39
December	28,190	62	39,859	42

TABLE VII.

Mean monthly catch of Hake, in cwts. per 100 *hours' fishing, in Region* 1, *Chart* 13, *with the mean monthly percentage of big Hake. Data supplied by the Statistical Section.*

Month.	1923.		1924.		1925.	
	Catch in cwts. per 100 hours.	Percentage of big hake.	Catch in cwts. per 100 hours.	Percentage of big hake.	Catch in cwts. per 100 hours.	Percentage of big hake.
January	24	18	70	23	127	13
February	27	24	82	17	122	8
March	32	22	49	15	82	9
April	49	34	56	32	81	19
May	89	37	160	29	144	21
June	110	38	144	32	171	27
July	121	49	96	32	108	20
August	85	35	89	22	96	18
September	59	34	76	18	72	15
October	57	34	54	16	71	10
November	54	29	56	21	85	9
December	68	29	84	15	107	8

TABLE VIII.

Catch of Hake, per 100 hours' fishing, compared with the landings of Hake, for the Region "West of Ireland" (Region 2, Chart 13). Data supplied by the Statistical Section.

Month.	1923.		1924.		1925.	
	Catch per 100 hours.	Landings of hake.	Catch per 100 hours.	Landings of hake.	Catch per 100 hours.	Landings of hake.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
January	59	292	138	6,535	113	2,473
February	125	140	205	6,101	116	4,476
March	59	277	153	12,104	101	5,093
April	152	3,140	152	20,279	132	10,479
May	163	17,911	280	27,603	183	29,865
June	153	13,533	233	28,126	228	35,361
July	178	13,721	202	37,414	226	42,503
August	159	23,888	233	25,527	243	22,067
September	125	13,340	217	20,669	208	18,814
October	129	16,411	162	20,961	168	15,401
November	104	9,453	126	15,870	137	12,271
December	147	6,880	134	7,316	117	9,847

TABLE IX.

Weekly mean landings of big and medium Hake at Cardiff, in Stones, per ship landing. Data from "Fish Trades Gazette."

Mid-point of week's Data. (1)	Peak of week's Data. (*See* Text.) (2)	Weekly mean Landing per Ship (Stones). (3)	Date of Moon's Phase. (4)	Mid-point of Week's Data. (1)	Peak of Week's Data. (*See* Text.) (2)	Weekly Mean Landing per ship (Stones). (3)	Date of Moon's Phase. (4)
	1922.						
Jan. 3– 4	4	131	1st Qr., 6	June 8	8	*1,440*	Full, 9
18	20	312	Full, 13	13–14	13	825	3rd Qr., 17
25	24	*345*	3rd Qr., 20	19–20	20	645	New, 25
Feb. 1	Jan. 31	168	New, 27	27–28	29	615	1st Qr., 1
7– 8	8	206	1st Qr. 4	July 4– 5	4	*645*	
14–15	16	244	Full, 11	13	13	420	Full, 9
21–22	20–21	*263*	3rd Qr., 18	18	19	480	3rd Qr., 16
Mar. 28– 1	Feb. 27	200	New, 26	25–26	25	585	New, 24
7– 8	6	165	1st Qr., 6	Aug. 1– 2	2	*655*	1st Qr., 31
14	14	155	Full, 12	9	9	477	Full, 7
21–22	22	*395*	3rd Qr., 19	22–23	21	*488*	3rd Qr., 15
28–29	28–29	270	New, 28	29–30	31	450	New, 22
Apr. 4–5	6	165	1st Qr., 5	Sept. 5	5	*600*	1st Qr., 29
11	12	*325*	Full, 11	12–13	12	525	Full, 6
18–19	19	315	3rd Qr., 18	19	18	467	3rd Qr., 14
25–26	26	340	New, 27	26–27	27	315	New, 21
May 2– 3	4	555	1st Qr., 4	Oct. 3– 4	2	273	1st Qr., 27
9–10	10	*675*	Full, 10	10–11	12	225	Full, 5
16–17	16	645	3rd Qr., 18	17–18	17	*300*	3rd Qr., 13
24–25	25	570	New, 26	24–25	24–25	236	New, 20
30–31	June 1	1,050	1st Qr., 2	Nov. 1	Oct. 31	180	1st Qr., 27

TABLE IX.—*Continued.*

Mid-point of week's Data. (1)	Peak of week's Data. (*See* Text.) (2)	Weekly Mean Landing per Ship. (Stones.) (3)	Date of Moon's Phase. (4)	Mid-point of week's Data. (1)	Peak of week's Data. (*See* Text.) (2)	Weekly Mean Landing per Ship. (Stones.) (3)	Date of Moon's Phase. (4)
	1922				1923		
Nov. 7–8	7	*188*	Full, 4	Nov. 6–7	5	346	New, 8
15	13	150	3rd Qr., 12	14	15	*400*	1st Qr., 14
21–22	21	*256*	New, 18	20–21	19	360	Full, 23
28–29	30	256	1st Qr., 26	27–28	28	406	3rd Qr., 30
Dec. 5–6	6	233	Full, 4	Dec. 4–5	3	526	New, 7
12–13	11	*293*	3rd Qr., 11	11–12	11–12	596	1st Qr., 14
19–20	20	202	New, 18	18–19	17	614	Full, 22
27–28	28	170					
	1923				1924		
Jan. 2–3	2	169	Full, 2	Jan. 1–2	2–3	*675*	
9–10	8	147	3rd Qr. 9	8–9	7	630	New, 6
16–17	16–17	127	New, 16	15–16	16	345	1st Qr., 13
23–24	25	244	1st Qr., 24	22–23	22–23	*435*	Full, 21
30–31	30–31	*259*	Full, 1	29–30	31	360	3rd Qr., 30
Feb. 6–7	5	353	3rd Qr. 8	Feb. 5–6	7	*540*	New, 4
13–14	12	120	New, 15	12–13	11	380	1st Qr., 12
20–21	21	*236*	1st Qr., 23	19–20	19	367	Full, 20
27–28	27	203	Full, 2	27	26–27	330	3rd Qr., 27
Mar. 6–7	5	206	3rd Qr., 9	Mar. 5	4	280	New, 5
13–14	13–14	320	New, 17	11–12	10	270	1st Qr., 13
20–21	22	*390*	1st Qr., 25	18–19	18–19	315	Full, 20
26–27	27	285	Full, 1	25–26	27	327	3rd Qr., 27
Apr. 4	5	370	3rd Qr., 7	Apr. 1–2	2–3	480	New, 4
10–11	12	417	New, 15	8–9	7	*555*	1st Qr., 12
17–18	19	432	1st Qr., 23	15	16	550	Full, 19
24–25	26	651	Full, 30	23	24	*1,093*	3rd Qr., 25
May 1–2	3	700	3rd Qr., 7	29–30	May 1	915	New, 3
8–9	10	*889*	New, 15	May 6–7	6	*1,585*	1st Qr., 11
15–16	17	440		13–14	15	1,240	Full, 18
23	24	860	1st Qr., 23	20–21	19	*1,460*	3rd Qr., 25
29–30	31	*922*	Full, 30	27–28	26	1,155	
June 5–6	7	814	3rd Qr., 7	June 3–4	2	1,215	New, 2
12	12	*840*	New, 14	11	10	*1,240*	1st Qr., 10
19–20	21	750	1st Qr., 21	17	17	1,160	Full, 16
26–27	28	788	Full, 28	24–25	26	1,085	3rd Qr., 23
July 3–4	5	900	3rd Qr., 5	July 1–2	1	875	New, 2
10–11	12	*945*	New, 13	8–9	7	585	1st Qr., 9
17–18	19	640	1st Qr., 20	15–16	14	675	Full, 16
24–25	26	*1,290*	Full, 27	22–23	23	750	3rd Qr., 23
Aug. 31–1	2	1,110	3rd Qr., 4	29–30	31	*830*	New, 31
7	6	506	New, 11	Aug. 6	5	693	1st Qr., 7
14–15	13	990	1st Qr., 18	12–13	12–13	690	Full, 14
20–21	22	*1,040*	Full, 25	19–20	18	705	3rd Qr., 22
28–29	29	764	3rd Qr., 3	26–27	25	*780*	New, 30
Sept. 4–5	4–5	600		Sept. 2–3	1	750	1st Qr., 6
11–12	11	*756*	New, 11	9–10	10	585	Full, 13
18–19	19	570	1st Qr., 17	16–17	16–17	525	3rd Qr., 20
52–26	26	*608*	Full, 24	23–24	25	480	New, 28
Oct. 2–3	2–3	526	3rd Qr., 2	Oct. 30–1	2	*705*	1st Qr., 5
10	9	*740*	New, 9	7–8	7–8	570	Full, 12
16–17	15	556	1st Qr., 16	14–15	15	*705*	
23–24	23	526	Full, 24	21–22	20	660	3rd Qr., 20
31	31	320	3rd Qr., 1	28–29	29	570	New, 28

TABLE IX.—*Continued.*

Mid-point of week's Data. (1)	Peak of week's Data. (*See* Text.) (2)	Weekly Mean Landing per Ship. (Stones.) (3)	Date of Moon's Phase. (4)	Mid-point of week's Data. (1)	Peak of week's Data. (*See* Text.) (2)	Weekly Mean Landing per Ship. (Stones.) (3)	Date of Moon's Phase. (4)
	1924				1925		
Nov. 4– 5	5	540	1st Qr., 3	Aug. 25–26	27	*750*	1st Qr., 27
11–12	11	450	Full, 11	Sept. 2	3	460	Full, 2
18–19	17	420	3rd Qr., 19	8– 9	7	530	3rd Qr., 10
25–26	25–26	330	New, 26	15–16	16	*600*	New, 18
Dec. 2– 3	3	375	1st Qr., 3	22–23	24	397	1st Qr., 25
9–10	9–10	390	Full, 11	29–30	Oct. 1	450	Full, 2
16–17	16–17	*435*	3rd Qr., 19	Oct. 6– 7	8	540	3rd Qr., 10
30	30	340		13–14	14	585	New, 18
	1925			20–21	21	*645*	
				27–28	27	467	1st Qr., 25
				Nov. 3– 4	5	345	Full, 1
Jan. 6– 7	8	182	Full, 10	10–11	12	345	3rd Qr., 9
13–14	14	510	3rd Qr., 18	17–18	16	435	New, 16
20–21	21	*525*	New, 24	24–25	24	*480*	1st Qr., 23
27–28	26	*525*	1st Qr., 31	Dec. 1– 2	2	*480*	Full, 30
Feb. 3– 4	5	450		8– 9	7	345	3rd Qr., 8
10–11	10–11	330	Full, 9	15–16	17	375	New, 16
17–18	18	430	3rd Qr., 16	29–30	31	*585*	1st Qr., 22
24–25	25	*450*	New, 23		1926		
Mar. 3– 4	3	250	1st Qr., 2				
10–11	11	*480*	Full, 10				
17–18	16	430	3rd Qr., 18	Jan. 5– 6	4	427	3rd Qr., 7
24–25	24–25	320	New, 24	12–13	13	465	New, 14
Apr. 31– 1	30–31	285	1st Qr., 1	19–20	20	*525*	1st Qr., 21
7	8	*500*	Full, 9	26–27	26–27	427	Full, 28
14	13	460	3rd Qr., 16	Feb. 2– 3	3	420	3rd Qr., 6
21–22	21	535	New, 23	9–10	10	*433*	New, 13
28–29	29	770	1st Qr., 1	16–17	17	390	1st Qr., 19
May 5– 6	4	*990*	Full, 8	23–24	24	278	Full, 28
12–13	11	725	3rd Qr., 15	Mar. 2– 3	3	*390*	3rd Qr., 7
19–20	19	765	New, 22	9–10	9–10	263	
26–27	26–27	930	1st Qr., 30	16–17	16–17	315	New, 14
June 3	2	980	Full, 6	23–24	22	345	1st Qr., 21
9–10	11	*1,050*	3rd Qr., 13	30	29	*383*	Full, 29
16–17	15	1,015	New, 21	Apr. 7	7	380	3rd Qr., 5
23–24	24	745	1st Qr., 29	13–14	14	405	New, 12
July 31– 1	30	960		20–21	22	405	1st Qr., 20
7– 8	7	*1,155*	Full, 6	27–28	27	600	Full, 28
14–15	13	750	3rd Qr., 12	May 11–12	13	970	New, 11
21–22	20	570	New, 20	18–19	17	1,215	1st Qr., 18
28–29	30	600	1st Qr., 28	26	25	900	Full, 27
Aug. 5	5	*780*	Full, 4	June 1	31	*1,180*	3rd Qr., 3
11–12	11	*780*	3rd Qr., 11	8– 9	7	1,065	New, 10
18–19	18–19	720	New, 19	15–16	14	870	1st Qr., 18

TABLE X.

Mean landings of Hake, in stones, at Cardiff, at new moon and full moon for the period 1922–1925

Phase of Moon.	Mean landing of hake (stones), 1922–1925.
1st Full Moon	335
New Moon	377
2nd Full Moon	307
New Moon	270
3rd Full Moon	286
New Moon	362
4th Full Moon	518
New Moon	649
5th Full Moon	925
New Moon	785
6th Full Moon	1,128
New Moon	778
7th Full Moon	827
New Moon	734
8th Full Moon	823
New Moon	748
9th Full Moon	660
New Moon	626
10th Full Moon	564
New Moon	545
11th Full Moon	445
New Moon	342
12th Full Moon	375
New Moon	409
13th Full Moon	428

TABLE XI.

The catches of big and medium Hake, in scores, per haul, with details of the hauls, on voyages where fishing was continuous, day and night.

Date.	Hours of towing.	Mid-time of tow.	Catch in Scores.
(1)	(2)	(3)	(4)
	"Trawler Prince."		
1925.			
May 4 ..	0900 to 1600	1230	17
	1600 to 2200	1900	15
„ 5 ..	2200 to 0400	0100	11
	0400 to 1000	0700	14
	1000 to 1600	1300	12
	1600 to 2300	1930	3
„ 6 ..	0300 to 1000	0630	10
	1000 to 1600	1300	12
	1600 to 2200	1900	10
„ 7 ..	2200 to 0400	0100	2
	0400 to 1000	0700	8
	1000 to 1600	1300	12
	1600 to 2200	1900	4
„ 8 ..	2200 to 0400	0100	6
„ 15 ..	0500 to 1100	0800	6
	1100 to 1700	1400	15
	1700 to 2300	2000	6
„ 16 ..	2300 to 0500	0200	4
	0500 to 1100	0800	7
	1100 to 1700	1400	7
	1700 to 2300	2000	5
June 1 ..	1600 to 2000	1800	12
„ 2 ..	2000 to 0300	2330	6½
	0300 to 0900	0600	9
	0900 to 1500	1200	25
	1500 to 2100	1800	22
„ 3 ..	2100 to 0500	0100	6
	0500 to 1100	0800	9
	1100 to 1700	1400	12
	1700 to 2300	2000	10
	"Trawler Prince."—*contd.*		
1925.			
June 4 ...	0500 to 1100	0800	8
	1100 to 1700	1400	14
	1700 to 2300	2000	13
„ 5 ..	2300 to 0500	0200	9½
	0500 to 1100	0800	23
	1100 to 1700	1400	26
	1700 to 2300	2000	13
„ 6 ..	2300 to 0500	0200	11
	0500 to 1100	0800	28
	1100 to 1700	1400	25
	1700 to 2300	2000	18
„ 7 ..	2300 to 0500	0200	7
	0500 to 1100	0800	18
	1100 to 1700	1400	17
	1700 to 2300	2000	18
„ 8 ..	2300 to 0500	0200	9
	0500 to 1100	0800	13
	1100 to 1700	1400	17
	1700 to 2300	2000	8
	"Tamura."		
Sept. 24	0430 to 0900	0645	10
	0900 to 1400	1130	8
	1400 to 1900	1630	14
	1900 to 2400	2130	3
„ 25	0000 to 0600	0300	2
	0600 to 1000	0800	12
	1000 to 1500	1230	10
	1500 to 2100	1800	6

TABLE XII.

Daily fluctuations in the mean weight of food per stomach in Hake.

Date. (1)	Hours of towing. (2)	Mid-haul. (3)	Mean wt. of food per stomach (gms.) (4)
	"Trawler Prince."		
1925.			
May 16..	2300 to 0500	0200	18·5
	0500 to 1100	0800	14·5
	1100 to 1700	1400	13
	1700 to 2300	2000	7
,, 23..	1700 to 2300	2000	23·6
,, 24..	2300 to 0500	0200	38
	0500 to 1100	0800	25
	1100 to 1700	1400	25
	1700 to 2300	2000	11
June 2..	2000 to 0300	2330	9
	0300 to 0900	0600	15
	0900 to 1500	1200	7·5
	1500 to 2100	1800	7·1
,, 3..	2100 to 0500	0100	10
	0500 to 1100	0800	12
	1100 to 1700	1400	9·5
	1700 to 2300	2000	5·5
,, 4..	0500 to 1100	0800	12
	1100 to 1700	1400	9
	1700 to 2300	2000	7·7
,, 5..	2300 to 0500	0200	13
	0500 to 1100	0800	14
	1100 to 1700	1400	12·5
	1700 to 2300	2000	9·6
,, 6..	2300 to 0500	0200	16
	0500 to 1100	0800	20
	1100 to 1700	1400	13
	1700 to 2300	2000	15
,, 7..	2300 to 0500	0200	15
	0500 to 1100	0800	13·5
	1100 to 1700	1400	11·4
	1700 to 2300	2000	19
,, 8..	2300 to 0500	0200	18
	0500 to 1100	0800	14
	1100 to 1700	1400	21
	1700 to 2300	2000	12
	Spawning hake off Hook Point. "Trawler Prince."		
July 10..	1900 to 2200	2030	4
,, 11..	2200 to 0330	0045	5
	0330 to 0700	0515	6
	0700 to 1130	0915	6
	1130 to 1600	1345	5

Date. (1)	Hours of towing. (2)	Mid-haul. (3)	Mean wt. of food per stomach (gms.) (4)
	Spawning hake off Hook Point. "Trawler Prince"—*contd.*		
1925.			
July 11..	1600 to 2030	1815	8
,, 12..	2100 to 0300	0000	4·4
	0300 to 0800	0530	6·5
	0800 to 1230	1015	5
	1230 to 1730	1500	6
	1730 to 2230	2000	5·1
,, 13..	2300 to 0500	0200	4·3
	0500 to 1000	0730	5·5
	1000 to 1500	1230	5
	1500 to 2000	1730	5·3
,, 14..	2000 to 0200	2300	6
	0200 to 0700	0430	4
	0700 to 1200	0930	5
	1200 to 1600	1400	5·7
	1600 to 2100	1830	5·6
,, 15..	2100 to 0200	2330	5·7
	0200 to 0730	0445	6·4
	0730 to 1130	0930	6
,, 19..	0400 to 0600	0500	18·5
	0600 to 0800	0700	14
	0800 to 1030	0915	9·7
	1030 to 1330	1200	11·6
	1330 to 1730	1530	9
	1730 to 2030	1900	16
,, 20..	2030 to 0130	2300	19·7
	0130 to 0330	0230	
	0330 to 0530	0430	20
	0530 to 0830	0700	
	0830 to 1130	1000	14·8
	1130 to 1630	1400	14
	1630 to 2030	1830	17·8
	2030 to 2330	2200	15
	"Tamura."		
Sept. 24	0430 to 0900	0645	23·4
	0900 to 1400	1130	16·9
	1400 to 1900	1630	21·8
	1900 to 2400	2130	25
,, 25	0000 to 0600	0300	35·4
	0600 to 1000	0800	23·6
	1000 to 1500	1230	18
	1500 to 2100	1800	24

Table XIII.

Number and Weight of Species forming the food of Big and Medium Hake.

(The factors used to ascertain the approximate weight of the various species are given in Table IV.)

Vessel	"Trawler Prince" II, III and IV	"Trawler Prince" V and VI	"Tamura I"		"Alida"	"Tamura II"	"Sir Mark Sykes"	"Tamura III"
Date of Voyage	May and June, 1925	July, 1925	September, 1925		November, 1925	Nov.–Dec., 1925	January, 1926	February, 1926
Position	51° 40′ N. to 52° 43′ N.	(V) Off the Hook (VI) 55° W. by S. of Smalls.	53° 45′ N.	Galway Bay	Donegal Bay	52° 46′ N.	St. Kilda	49° 50′ to 50° 16′ N.
Depth	120–300 fms.*	40 and 55 fms.	170 fms.	60 fms.	50 fms.	220 fms.	180 fms.	250 fms.
Number of hake taken	—	—	183	243	616	452	—	—
Weight of food per fish	—	—	88 gms.	259 gms.	35 gms.	50 gms.	—	—

FOOD SPECIES.	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight
Gadus Poutassou (large)	167	30,060	49·8				56	10,080	62·5							83	14,940	66·6	23	4,140	54·2	74	13,320	70·2
,, ,, (small)																								
Gadiculus argenteus ...	50	800	1·3				49	784	4·9							1	16	0·1	15	240	3·1	47	752	4·0
Hake	41	14,350	23·8	12	4,200	19·0	10	3,500	21·7	40	14,000	22·2	4	1,400	6·5	16	5,600	24·9	2	700	9·2	11	3,850	20·3
Cephalopods	15	1,200	2·0	1	80	0·4	18	1,440	8·9				11	880	4·1	3	240	1·1	22	1,760	23·0	5	400	2·1
Smelts	25	750	1·2	4	120	0·5	1	30	0·2	1	30	0·1	5	150	0·7	5	150	0·7				8	240	1·3
Mackerel (big) ...	22	13,200	21·9	17	10,200	46·2																		
,, (small) ...										135	40,500	64·4	33	9,900	46·2									
Clupeoids				63	6,300	28·5				70	7,000	11·1	38	3,800	17·7									
Horse-mackerel (Caranx)										2	1,000	1·6	5	2,500	11·7	2	1,000	4·4	1	500	6·6			
Other forms	In	cluded smelts	in	12 (a)	1,200	5·4	3 (b)	300	1·8	4	400	0·6	28 (c)	2,800	13·1	5 (d)	500	2·2	3 (e)	300	3·9	4 (f)	400	2·1
Total		60,360			22,100			16,134			62,930			21,430			22,446			7,640			18,962	

* Mean depth taken as 150 fms.

(a) 2 megrims, 4 bib, 4 motella, 2 crystallogobius.
(b) 2 witches, 1 nephrops.
(c) 23 bib, 3 witches, 1 gurnard, 1 callionymus.
(d) 4 megrims, 1 nephrops.
(e) 1 gurnard, 1 bib, 1 bream.
(f) 1 megrim, 1 phycis, 2 munida; besides 4 small specimens of *Scopelus Müllerí*.

TABLE XIII.—*continued.*

Vessel / Date of Voyage / Position / Depth	"Tamura III" February, 1926 Off Old Head of Kinsale 65 fms.			"Tamura IV" March, 1926 53° 35′ N. 12° 15′ W. 160 fms.			"Tamura V" April, 1926 52° 40′ N. 12° 05′ W. 125 fms.			"Tamura VI" June, 1926. 52° 45′ N. 11° 40′ W. 100 fms.			"Tamura VII" June, 1926 52° 25′ N. 11° 36′ W. 95 fms.			"Tamura VIII" July, 1926 52° 35′ N. 130 fms.			"Tamura IX" October, 1926 Porcupine Bank 175 fms.		
Number of hake taken	—			706			705			877			986			910			531		
Weight of food per fish	—			43 gms.			47 gms.			33 gms.			41 gms.			63 gms.			52 gms.		
FOOD SPECIES.	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight	No. of Specimens	Approx. Weight	% by Weight
Gadus Poutassou (large)				76	13,680	45·1	122	21,960	66·5	76	13,680	47·1	36	7,381	18·3	77	17,396	30·5	118	21,461	77·3
,, ,, (small)													53			208			13		
Gadiculus argenteus				187	2,992	9·8	52	832	2·5	39	624	2·1	6	96	0·2	29	464	0·8	22	352	1·3
Hake	2	700	4·0	37	12,950	42·7	20	7,000	21·2	22	7,700	26·6	21	7,350	18·2	26	9,100	16·0	16	5,600	20·2
Cephalopods				4	320	1·0	6	480	1·4	32	2,560	8·8	31	2,480	6·1	46	3,680	6·4	3	240	0·9
Smelts	7	210	1·2	7	210	0·7	5	150	0·5	2	60	0·2	2	60	0·1	14	420	0·7	3	90	0·3
Mackerel (big)	12	7,200	86·4				4	2,400	7·3				19	11,400	28·3	31	18,600	32·6			
,, (small)	27	8,100																			
Clupeoids	14	1,400	7·9																		
Horse-mackerel (Caranx)										8	4,000	13·8	22	11,000	27·3	14	7,000	12·3			
Other forms	1 (*g*)	100	0·5	2 (*h*)	200	0·7	2 (*i*)	200	0·6	4 (*j*)	400	1·4	6 (*k*)	600	1·5	4 (*l*)	400	0·7	(*m*)		
Total		17,710			30,352			33,022			29,024			40,367			57,060			27,743	

(*g*) Whiting (or *Gadus esmarckii*).
(*h*) Phycis; besides several small Pasiphaea and Pandalus, and 5 specimens of *Scopelus* (?) *Mülleri*.
(*i*) 1 Portunus, 1 nephrops, 4 *Scopelus Mülleri*.
(*j*) 2 bib, 2 megrims.
(*k*) Bib, or *Gadus esmarckii*.
(*l*) 1 bib, 1 piper, 2 megrims.
(*m*) 1 *Maurolicus Pennanti*, 4 *Scopelus Mülleri*.

TABLE XIV.

The seasonal change in the intensity of feeding compared with the condition of the roe in mature ♀ and ♂ Hake.

Voyage (*see* Table XIII).	Mean approx. depth of voyage.	Mean weight of food per fish (whole trip).	Mean weight of roe of ♀ hake (84·5–89·5 cms.).	Mean weight of milt of ♂ hake (69·5–74·5 cms.).
	Fms.	Gms.	Gms.	Gms.
Tamura I	170	88	70	—
	60	259	164	—
Tamura II	220	50	58	11
Alida	50	35	146	24
Tamura IV	160	43	173	38
Tamura V	125	47	207	51
Tamura VI	100	33	226	46
Tamura VII	95	41	262	43
Tamura VIII	130	63	179	38
Tamura IX	175	52	26	8

TABLE XV.

Landings of Hake from the area South-East of Ireland (*Chart* 13, "*S.E.*").

Month.	1924.		1925.		1926.	
	Big Hake.	Small Hake.	Big Hake.	Small Hake.	Big Hake.	Small Hake.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
January	44	345	29	768	18	511
February	84	343	74	720	3	81
March	76	557	52	400	57	842
April	95	561	191	847	124	1,207
May	953	1,538	626	2,347	1,457	3,629
June	2,756	3,115	6,581	6,776	3,321	3,204
July	2,521	3,189	2,696	5,708	2,629	3,755
August	1,733	4,647	2,704	8,524	1,248	3,274
September	1,030	4,857	1,409	5,234	1,007	4,184
October	185	4,027	951	7,463	865	4,242
November	696	4,519	339	3,013	212	1,720
December	251	2,254	320	3,697	217	1,916

NOTE.—The figures for August, 1926, onwards have become available since the completion of the report and have not been used in the preparation of Fig. 12.

TABLE XVI.

Sea-surface temperatures at Coningbeg Lightship (10-*day means*). *Data supplied by the courtesy of Mr. G. P. Farran and the Irish Department of Fisheries.*

Date. (1)	Dawn T. °C. (2)	4.0 p.m. T. °C. (3)	Date. (1)	Dawn T. °C. (2)	4.0 p.m. T. °C. (3)
	1924		Sept. 5 ..	13·92	14·14
Oct. 24–31 ..	12·25	12·41	15 ..	·78	·00
Nov. 5 ..	11·74	11·86	25 ..	·52	13·76
15 ..	·35	·52	Oct. 5 ..	·42	·66
25 ..	·10	·14	15 ..	·02	·25
Dec. 5 ..	10·78	10·76	25 ..	12·95	·05
15 ..	·50	·42	Nov. 5 ..	·34	12·36
25 ..	·11	·02	15 ..	11·28	11·38
	1925		25 ..	10·34	10·60
			Dec. 5 ..	9·55	9·76
Jan. 5 ..	9·02	9·10	15 ..	8·78	8·78
15 ..	·04	·14	25 ..	·36	·40
25 ..	·11	·13		1926	
Feb. 5 ..	8·80	8·88			
15 ..	8·54	·38	Jan. 5 ..	8·30	8·26
25 ..	·15	·32	15 ..	·08	·08
Mar. 5 ..	7·84	8·06	25 ..	·12	·14
15 ..	·90	·18	Feb. 5 ..	·14	·18
25 ..	·80	7·98	15 ..	·18	·17
Apr. 5 ..	7·92	8·26	25 ..	·35	·35
15 ..	8·46	·66	Mar. 5 ..	·32	·32
25 ..	·50	·92	15 ..	·54	·68
May 5 ..	·88	9·30	25 ..	·33	·42
15 ..	9·42	·76	Apr. 5 ..	·48	·72
25 ..	·96	10·27	15 ..	·76	·96
June 5 ..	10·48	11·69	25 ..	·94	9·50
15 ..	12·34	13·83	May 5 ..	9·30	·60
25 ..	11·90	13·26	15 ..	9·44	10·18
July 5 ..	13·31	·64	25 ..	11·00	11·50
15 ..	·12	·67	June 5 ..	10·96	11·38
25 ..	·15	·95	15 ..	11·58	12·16
Aug. 5 ..	12·97	·57	25 ..	12·25	13·01
15 ..	13·94	14·38			
25 ..	·89	·28			

TABLE XVII.

Mean monthly temperatures of the sea-surface at Sevenstones Lightship, with the number of observations taken into account in calculating the monthly average.

Month.	1923.		1924.		1925.		1926.	
	T. °C.	No. of Observations.	T. °C.	No. of Observations.	T. °C.	No. of Observations.	T. °C.	No. of Observations.
January ..	9·8	11	9·4	11	10·8	12	10·0	11
February ..	9·5	10	8·9	11	10·0	12	9·8	11
March ..	9·6	10	8·6	12	9·2	11	10·0	11
April	9·7	11	8·9	11	9·8	11	10·6	11
May	10·3	12	10·8	11	10·7	18	11·5	11
June	12·5	11	13·1	11	13·6	21	13·6	11
July	15·85	11	14·4	11	15·3	15	16·2	11
August ..	15·55	11	14·8	11	15·3	11	17·4	11
September ..	14·08	11	14·0	11	14·0	11	16·2	11
October ..	12·76	11	13·0	11	13·5	11	14·1	11
November ..	10·86	11	11·9	11	11·8	11	11·9	11
December ..	9·76	11	11·2	11	10·6	10	10·7	11

TABLE XVIII.

The catches of Hake in the shallow-water area "South-East of Ireland" compared with the catches of Hake in the whole South-western area.

Month.	1923.		1924.		1925.	
	South-East of Ireland.	Whole South-Western area.	South-East of Ireland.	Whole South-Western area.	South-East of Ireland.	Whole South-Western area.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
January	1,974	10,262	498	22,798	837	29,184
February	898	10,129	513	29,788	926	36,918
March	747	13,440	786	20,394	576	30,200
April	913	24,105	799	20,413	1,321	31,423
May	1,972	41,433	3,473	58,354	4,124	42,835
June	4,590	53,863	8,531	54,549	18,774	62,725
July	9,565	61,670	7,129	31,181	11,426	34,131
August	9,610	34,365	8,335	27,656	14,553	34,412
September	4,230	17,656	7,542	23,425	8,409	23,084
October	5,086	12,626	4,856	13,209	10,093	19,684
November	6,175	12,974	5,996	12,717	4,352	20,727
December	1,823	18,202	2,801	25,444	5,130	30,181

TABLE XIX.

Landings of Hake from the region "West of Scotland." (Chart 13, Region 3.)

Month.	1923.		1924.		1925.	
	Big Hake.	Small Hake.	Big Hake.	Small Hake.	Big Hake.	Small Hake.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.
January	239	4,490	51	822	134	1,437
February	132	1,426	142	849	260	1,580
March	332	2,724	347	1,799	1,667	5,388
April	1,253	3,913	1,905	4,123	2,456	6,044
May	862	4,399	377	1,628	1,237	6,071
June	1,386	3,566	565	2,763	1,244	5,590
July	1,480	4,253	1,082	5,384	1,014	10,908
August	1,400	6,819	410	4,057	1,507	17,107
September	999	6,089	986	5,101	1,611	15,810
October	718	9,511	688	6,612	1,143	15,865
November	732	9,763	563	5,312	850	14,780
December	579	5,735	293	4,848	725	11,421

TABLE XX.

Landings of Hake from the Irish Sea (Chart 13, Region 4), together with the mean sea-surface temperatures on Holyhead-Kingstown route (partly from Bulletin Hydrographique).

Month.	1923.		1924.		1925.		1923.	1924.	1925.
	Big Hake.	Small Hake.	Big Hake.	Small Hake.	Big Hake.	Small Hake.	°C.	°C.	°C.
	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.	Cwts.			
January	191	128	254	67	142	12	8·6	7·9	8·9
February	130	235	372	99	398	29	8·3	7·1	6·5
March	133	224	612	115	417	93	8·3	5·8	6·8
April	265	240	526	190	701	472	8·7	7·8	7·8
May	1,202	748	1,341	536	111	120	9·2	9·1	8·3
June	820	909	1,202	452	144	680	11·3	11·8	11·7
July	1,501	1,841	1,816	1,462	679	1,788	13·5	12·5	12·8
August	894	452	1,247	614	658	1,203	13·2	13·5	14·4
September ..	895	303	950	695	469	816	13·0	12·7	13·9
October	841	362	1,242	477	723	310	11·6	11·9	13·5
November ..	449	250	560	146	174	38	9·8	11·5	11·9
December	333	91	431	71	148	88	8·5	10·8	9·9

NOTE.—The quantities landed at Liverpool from the Statistical Region VII N.D. are included in this table on the assumption that practically the whole of these landings consist of fish taken within the limits of the "Irish Sea" indicated on Chart 13, Region 4.

TABLE XXI.

Landings of Hake from the Northern North Sea (Chart 13, Regions 5 and 6).

Month.	1924.		1925.	
	Big Hake.	Small Hake.	Big Hake.	Small Hake.
	Cwts.	Cwts.	Cwts.	Cwts.
January	29	17	103	80
February	—	8	25	69
March	177	504	414	1,683
April	581	1,642	408	1,415
May	660	3,209	459	1,356
June	574	1,677	201	764
July	337	830	97	384
August	46	236	14	112
September	37	23	17	42
October	50	230	48	192
November	159	235	182	200
December	129	82	150	178

TABLE XXII.

Fortnightly means of daily observations of surface temperature at Fair Isle and Monach Lighthouses (in °C.).

FAIR ISLE. MONACH.

Month.	1923.	1924.	1925.	Mean.	Month.	1924.	1925.
Jan. 1st Half	—	6·15	8·43	7·29	Jan. 1st Half	7·95	8·03
2nd ,,	7·62	6·55	8·08	7·42	2nd ,,	7·93	7·48
Feb. 1st ,,	7·63	6·06	7·65	7·11	Feb. 1st ,,	5·25	6·74
2nd ,,	6·42	5·62	7·35	6·46	2nd ,,	4·61	6·54
Mar. 1st ,,	6·78	6·28	7·03	6·70	Mar. 1st ,,	6·18	7·51
2nd ,,	7·59	6·61	7·34	7·18	2nd ,,	6·61	7·51
Apr. 1st ,,	7·34	7·41	8·13	7·63	Apr. 1st ,,	5·85	7·89
2nd ,,	7·81	8·89	9·21	8·64	2nd ,,	7·25	7·95
May 1st ,,	8·30	9·01	10·79	9·37	May 1st ,,	7·26	8·30
2nd ,,	9·53	10·74	10·81	10·36	2nd ,,	8·02	8·65
June 1st ,,	9·61	10·86	13·23	11·23	June 1st ,,	12·08	11·57
2nd ,,	10·48	12·50	12·88	11·95	2nd ,,	12·11	12·46
July 1st ,,	13·43	13·72	15·25	14·13	July 1st ,,	12·57	Owing to defective thermometer, readings from July –Sept., 1925, inclusive were found to be unreliable.
2nd ,,	13·10	14·94	15·39	14·48	2nd ,,	12·57	
Aug. 1st ,,	13·39	14·65	14·52	14·19	Aug. 1st ,,	14·18	
2nd ,,	13·21	14·94	14·03	14·06	2nd ,,	13·79	
Sept. 1st ,,	11·74	13·45	11·84	12·34	Sept. 1st ,,	13·97	
2nd ,,	11·31	12·32	11·78	11·80	2nd ,,	13·22	
Oct. 1st ,,	10·33	11·67	10·41	10·80	Oct. 1st ,,	11·91	11·31
2nd ,,	9·93	10·41	9·95	10·10	2nd ,,	11·51	10·95
Nov. 1st ,,	8·83	9·57	8·83	9·08	Nov. 1st ,,	9·89	7·81
2nd ,,	6·91	9·85	7·81	8·19	2nd ,,	9·39	6·21
Dec. 1st ,,	7·65	9·51	6·53	7·90	Dec. 1st ,,	9·09	6·03
2nd ,,	6·16	8·94	6·23	7·11	2nd ,,	8·95	4·41

TABLE XXIII.

Comparison between the catch of Hake per hour, and the abundance of ultimate food, as deduced from the weight of this food per stomach in Blue Whiting. July, 1926. *Lat.* 52° 35′ *N.,* 120 *Fathoms.*

Number of Sample.	Date.	Hours of Tow.	Catch in Boxes.	Catch per Hour.	Mean weight food per stomach.
	1926.			Cwts.	Grammes.
1	July 11 ..	0430 to 0930	8	1·6	1·3
2	„ 11 ..	0930 to 1530	10	1·7	1·8
3	„ 13 ..	0430 to 0930	10	2·0	3·1
4	„ 13 ..	0930 to 1530	10	1·7	2·2
5	„ 14 ..	0430 to 0930	5	1·0	1·8
6	„ 14 ..	0930 to 1530	12	2·0	2·1
7	„ 15 ..	0430 to 0930	13	2·6	4·1
8	„ 16 ..	0430 to 0930	17	3·4	2·6
9	„ 17 ..	0430 to 0930	7	1·4	3·6

TABLE XXIV.

Comparison between the catch per hour of Hake, and the abundance of Kril, as shown by the percentage of small Hake stomachs containing it. March, 1925. *Lat.* 51° 10′ *N. to Lat.* 50° 50′ *N.,* 180–300 *fathoms.*

Number of Observation.	Date.	Hours of Tow.	Catch in Scores.	Catch in Scores per Hour.	Percentage small Hake containing Kril.
	1925.				
1	March 18 ..	1130 to 1700	6	1·1	87
2	„ 19 ..	0630 to 1100	5	1·1	90
3	„ 20 ..	0500 to 1100	4½	0·8	18
4	„ 21 ..	0530 to 1130	2½	0·4	12
5	„ 21 ..	1130 to 1700	3	0·5	8
6	„ 22 ..	0530 to 1100	6	1·1	14
7	„ 23 ..	0530 to 1130	8	1·3	47
8	„ 23 ..	1130 to 1730	4	0·7	13

TABLE XXV.

Relation between the catch of Hake and the local abundance of Kril, as deduced from the mean weight of Kril per stomach in Blue Whiting. Lat. 52° 25′ *N. to Lat.* 52° 45′ *N.,* 100 *fathoms.*

Sample Number.	Date.	Hours of Tow.	Catch in Boxes.	Catch in Cwts. per Hour.	Mean weight Kril per stomach.
	1926.				Grammes.
1	May 30 ..	0430 to 0930	13	2·6	2·1
2	„ 31 ..	0430 to 0930	11	2·2	2·5
3	June 1 ..	0330 to 0930	8	1·3	1·2
4	„ 12 ..	0430 to 0930	4	0·8	0·85
5	„ 14 ..	0430 to 0930	10	2·0	1·6

As above, but deducing the abundance of Kril from the weight per stomach in small Hake. Lat. 51° 40′ *N.,* 150–250 *fathoms.*

	1925.				
1	May 7 ..	0400 to 1000	6	1·0	0·6
2	„ 9 ..	0400 to 1000	5	0·8	0·4
3	„ 15 ..	0500 to 1100	6	1·0	2·0
4	„ 15 ..	1100 to 1700	12	2·0	1·4
5	„ 16 ..	0500 to 1100	6	1·0	0·8
6	„ 19 ..	0500 to 1100	15	2·5	2·4

TABLE XXVI.

Comparison between the catch of Hake per hour and the abundance of ultimate food, as deduced from the weight of food per stomach in Blue Whiting. June 1925. *Lat.* 52° 50′ *N.*, 120 *fathoms.*

Number of Sample.	Date.	Hours of Tow.	Catch in boxes.	Catch per Hour.	Mean weight of food per stomach.
	1925.			Cwts.	Grammes.
1	May 31 ..	0830 to 1200	5	1·4	2·4
2	June 2 ..	0900 to 1400	20	4·0	1·5
3	,, 3 ..	0500 to 1100	7	1·2	2·4
4	,, 4 ..	0500 to 1100	7	1·2	2·3
5	,, 5 ..	0500 to 1100	20	3·3	1·6
6	,, 6 ..	0500 to 1100	24	4·0	1·4
7	,, 7 ..	0500 to 1100	15	2·5	1·5
8	,, 8 ..	0500 to 1100	11	1·8	2·0

As above. Porcupine Bank. 170 *fathoms. October,* 1926.

Number of Sample.	Date.	Hours of Tow.	Catch in boxes.	Catch per hour.	Mean weight of food per stomach.	Mean weight of Kril per stomach.
	1926.			Cwts.	Grammes.	Grammes.
1 ..	Oct. 18 ..	0600 to 1000	7	1·7	·18	·18
2 ..	,, 19 ..	0500 to 1200	12	1·7	·36	·14
3 ..	,, 19 ..	1200 to 1900	8	1·1	·92	·38
4 ..	,, 20 ..	0500 to 1200	10	1·4	·63	·22
5 ..	,, 21 ..	0500 to 1200	10	1·4	1·4	·61
6 ..	,, 23 ..	0500 to 1200	6	0·9	·4	·17
7 ..	,, 24 ..	0500 to 1200	4	0·6	1·04	·56

DESCRIPTION OF CHARTS.

Charts 1 to 12 ..	The Distribution of Hake in various months of 1923, 1924 and 1925, as drawn from statistical data. The numbers refer to the arbitrary groups in Table 1. Areas including groups 4 and higher (more than 150 cwt. per 100 hours' fishing) are more heavily stippled.
Chart 13.. ..	The Regions 1 to 7, into which the Hake fishing grounds about the British Isles are divided for discussion in the text. Sea-areas not included in these Hake regions are stippled.
Chart 14.. ..	The Statistical Area "South-East of Ireland." Chart shewing the main features of the area.
Chart 15.. ..	The Distribution of Hake in the North Sea area in terms of catch in cwt per 100 hours' fishing. Average for the year 1924.
Chart 16.. ..	The Distribution of Hake in the North Sea area in terms of catch in cwt per 100 hours' fishing. Average for the year 1925.
Chart 17.. ..	The 50, 70 and 100 fathom lines in the North Sea area.
Chart 18.. ..	The Surface Currents of the North Sea, August; after Böhnecke.

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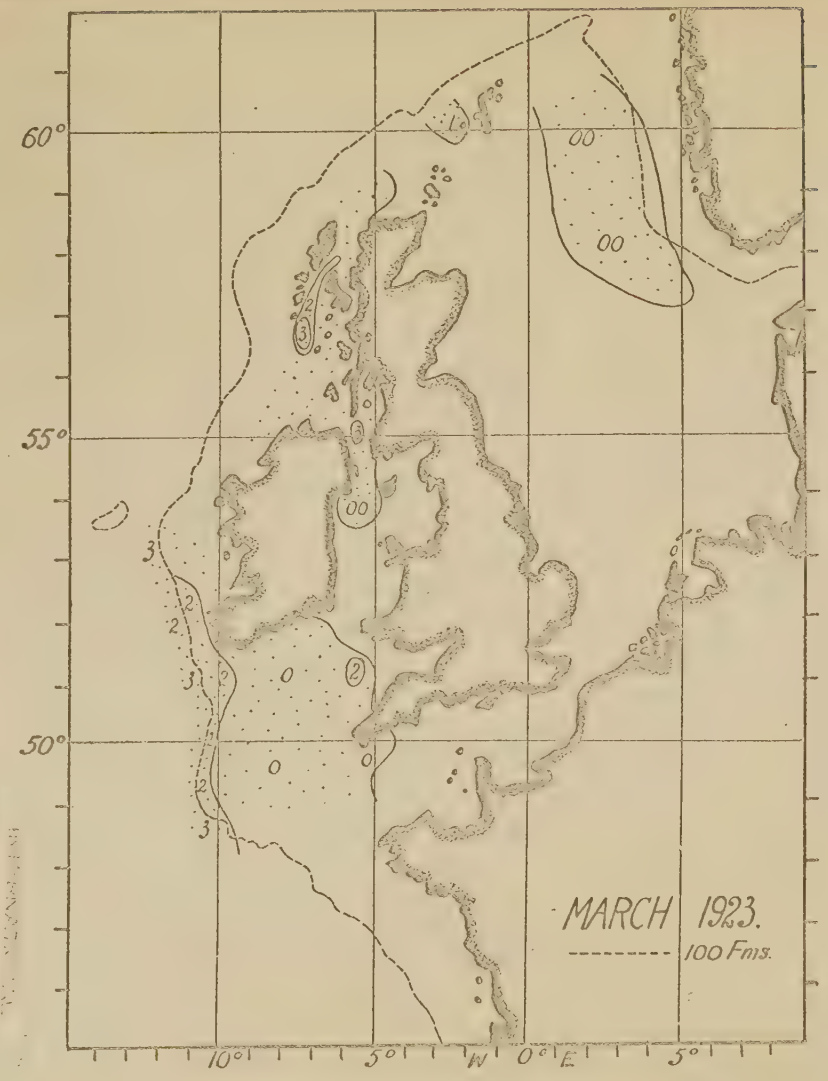


CHART 1.

P1405 7460 6/23 S&S 11,250 1/23

CHART. 2.

P1405.

CHART 3.

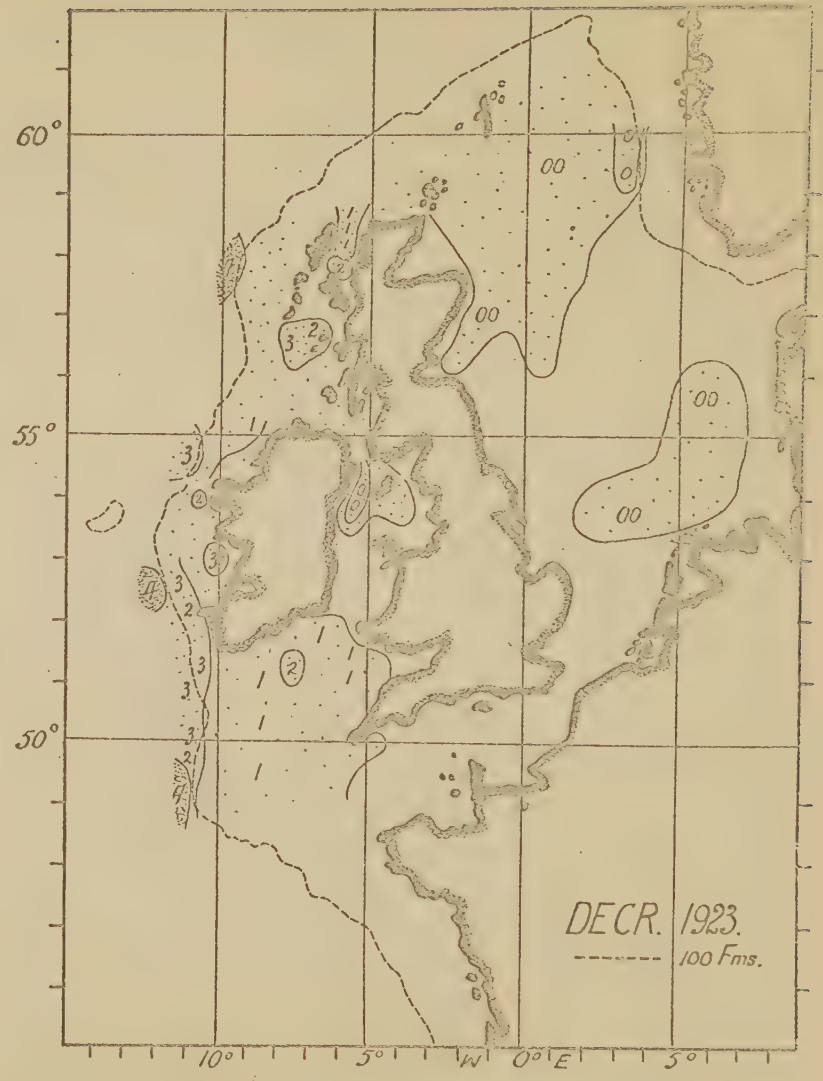
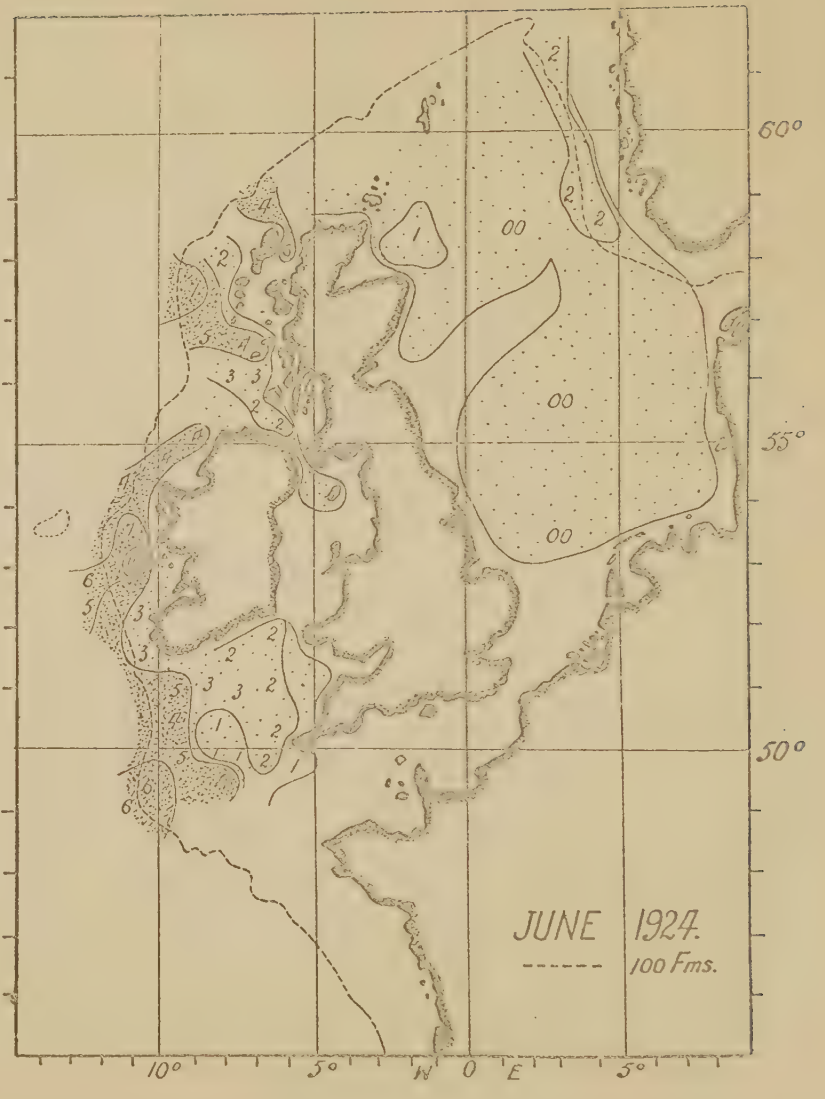


CHART 4.

CHART 5.

P.1405



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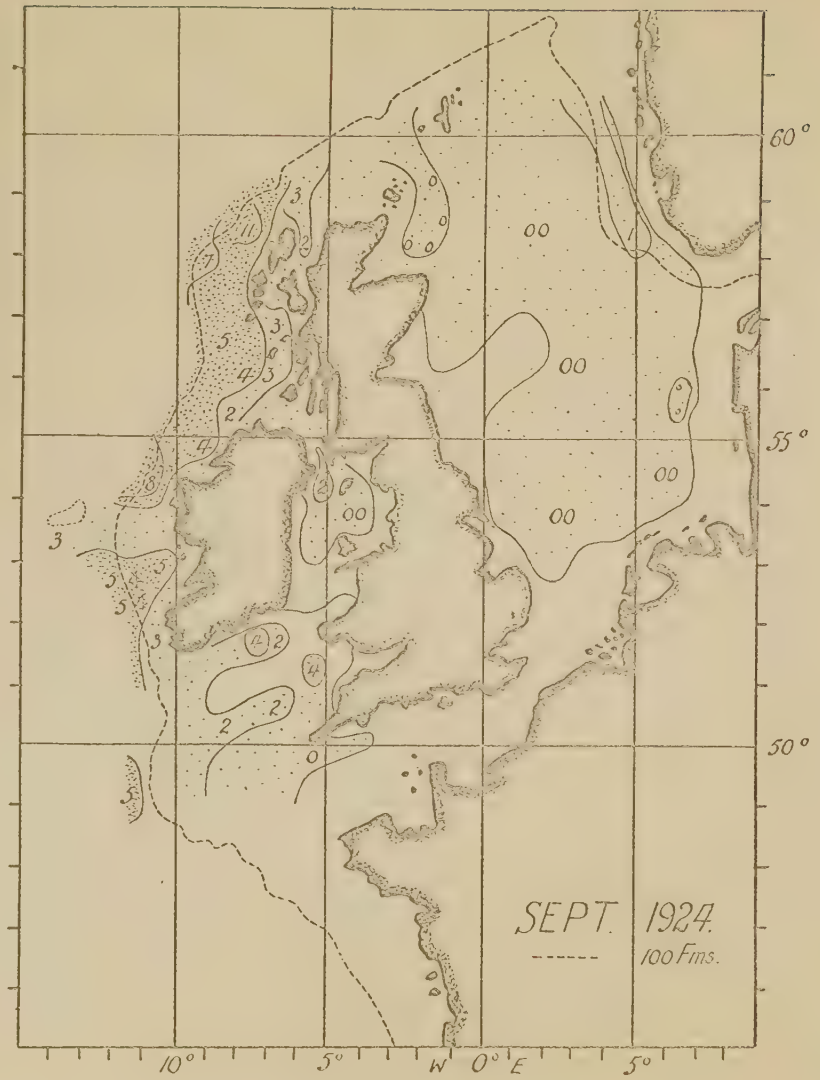

CHART 7.

CHART 8.

CHART 9.

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CHART 10.

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CHART 11.

P1405

CHART 12.

P1405

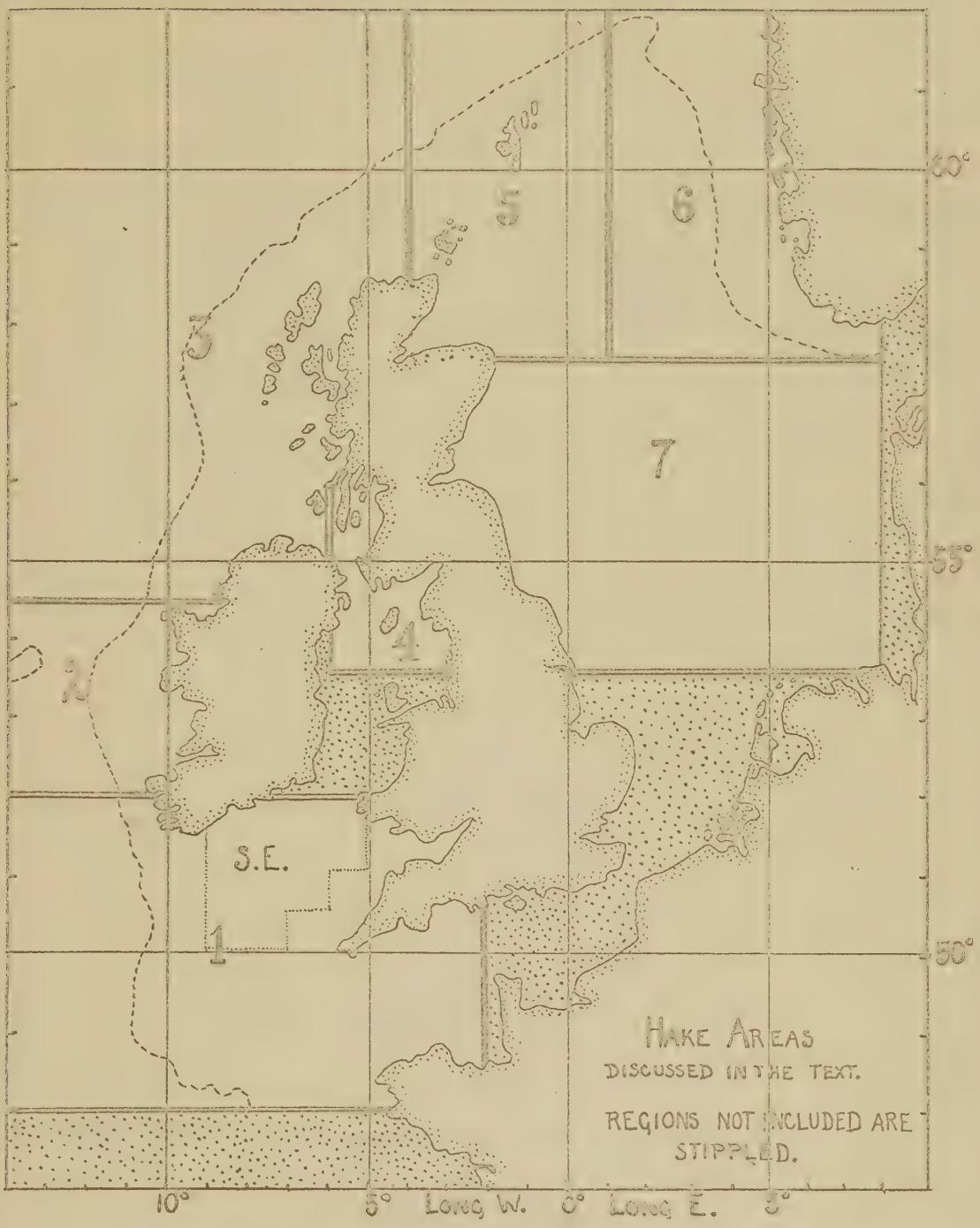

CHART 13.

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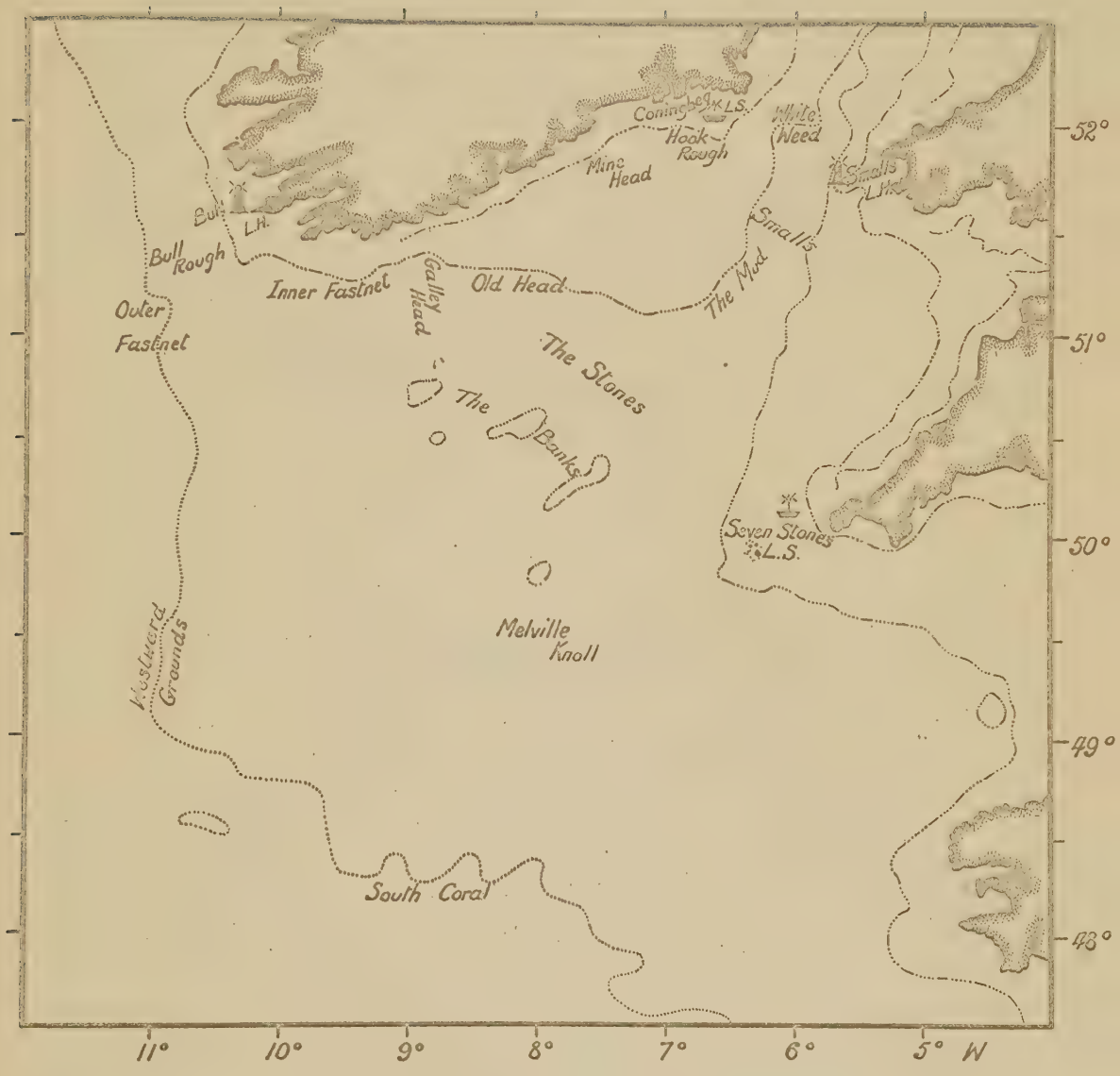

CHART 14.

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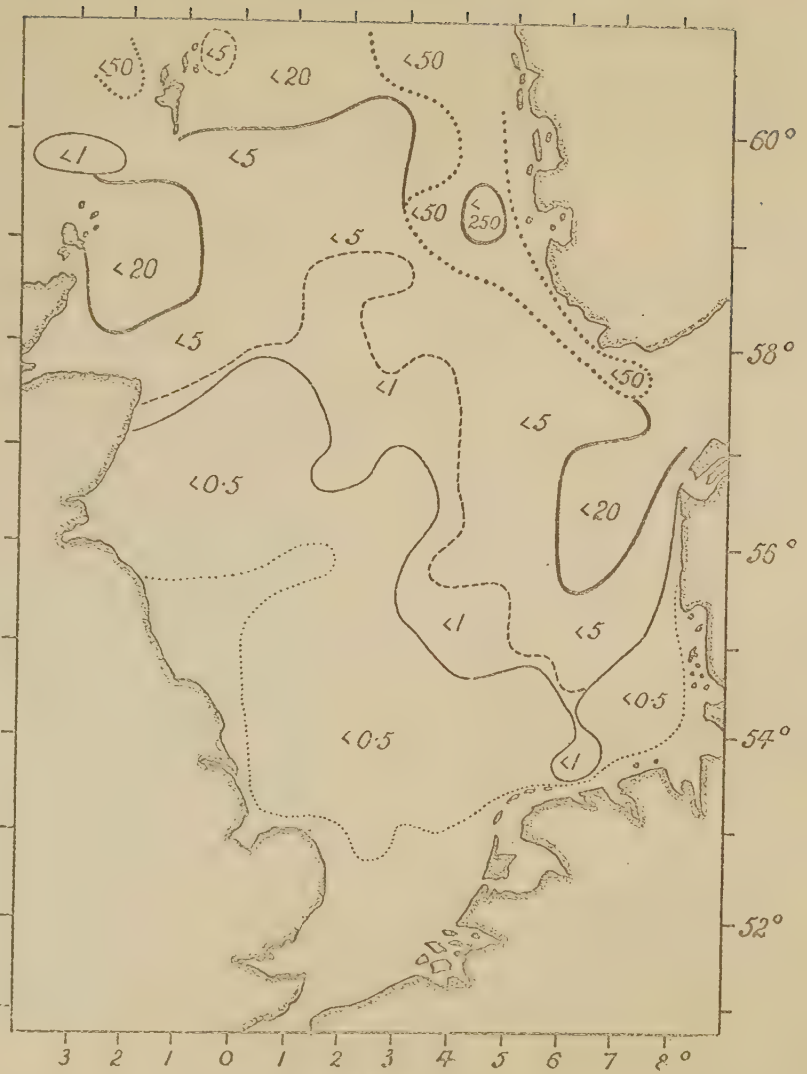


CHART 15.

YEAR. 1924

P.1405

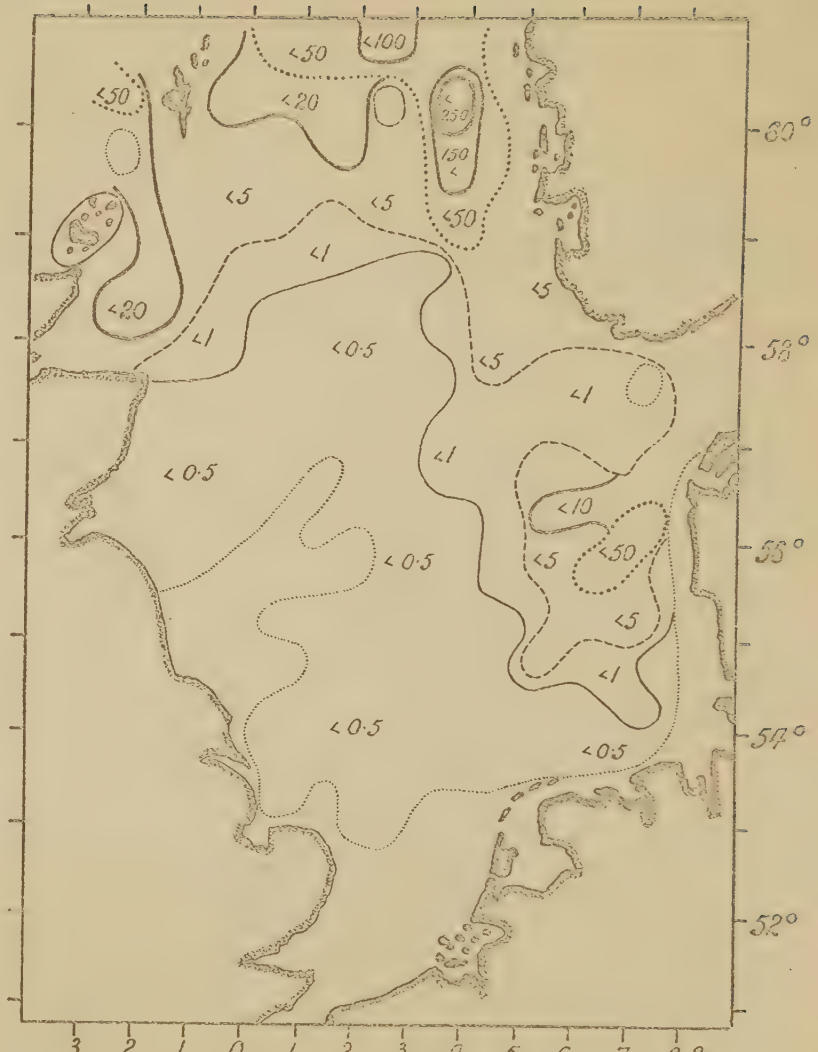
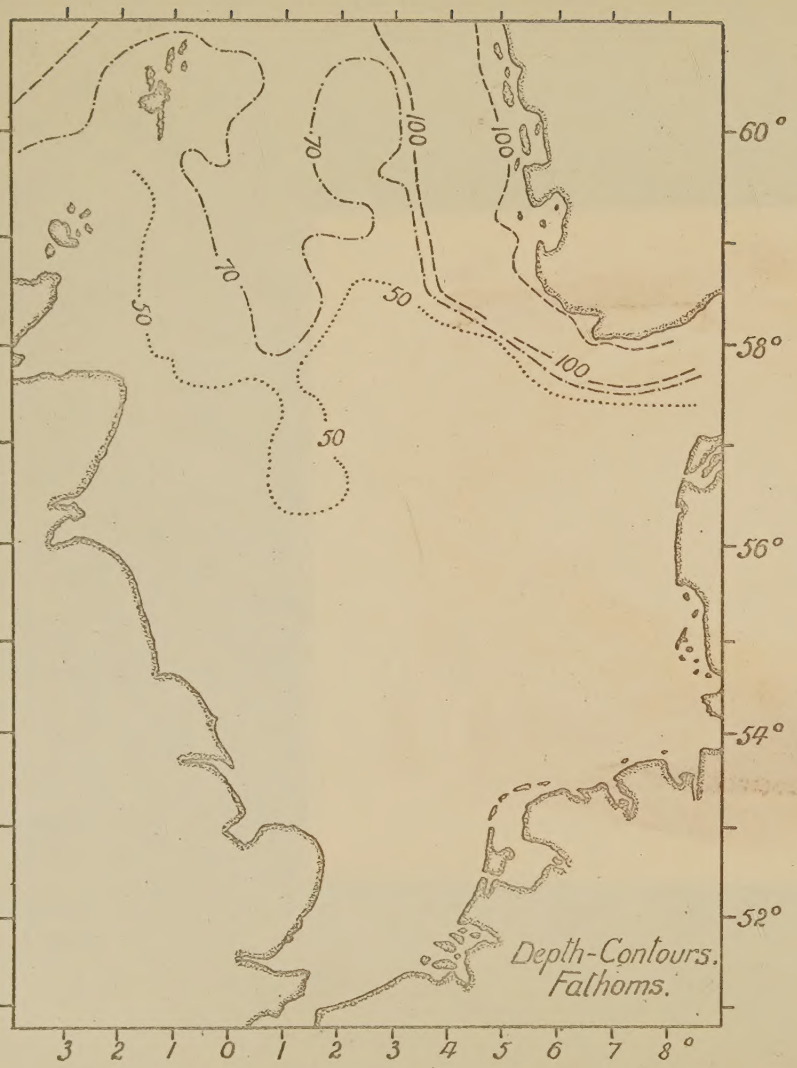


CHART 16.

YEAR. 1925

P.1405



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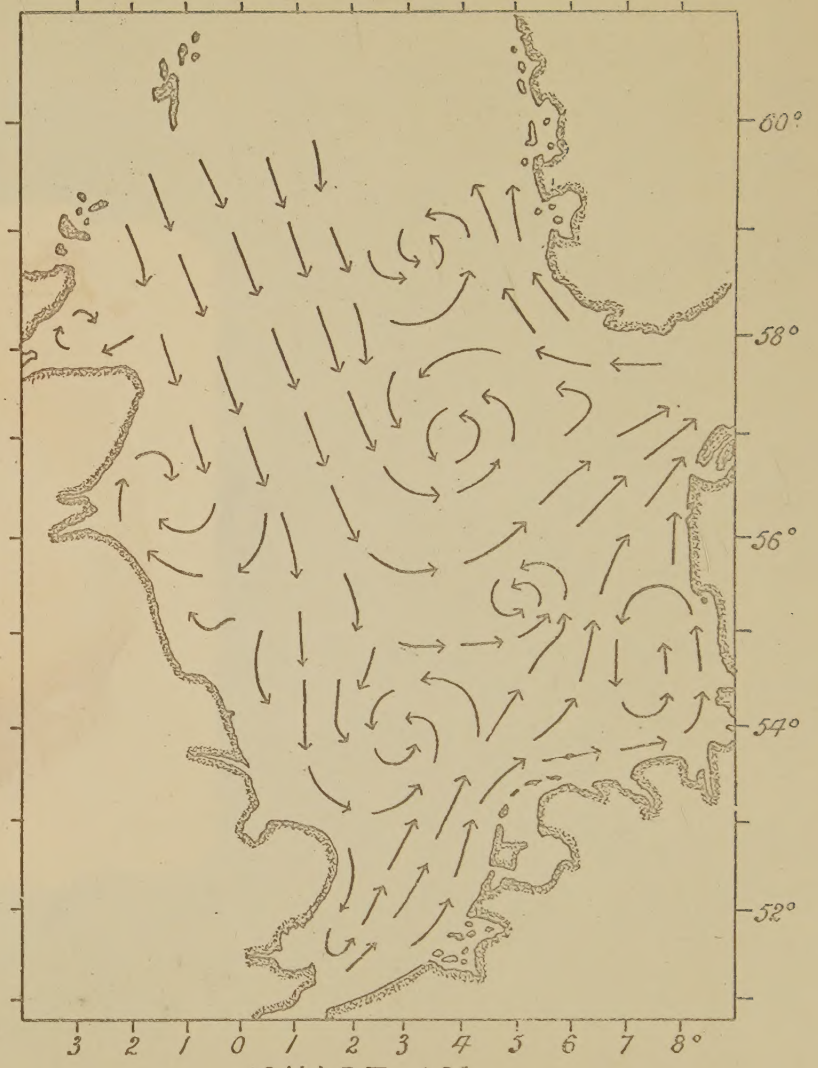

CHART 18.

P.1405.

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